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Iron and Steel Production in America.

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Some Modern Conditions and Recent Developments in Iron and Steel Production in America.

A REPORT

To the Electors to the Gartside Scholarships on the results of a Tour in the United States in 1903-04.

BY

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PREFACE.

THE following pages contain an account of a visit to some of the more important centres of iron and steel production in the United States of America, made by the writer as Gartside Scholar of the University of Manchester. The visit dated from September, 1903, until April, 1904. Of this period, three months were spent as assistant in the laboratory of a large steel works in Pennsylvania, the remainder in travelling.

The scope of the investigation and of the Report need some explanation. No exhaustive treatment of the iron and steel industry as a whole has been attempted, and, although many branches of production have been touched upon, emphasis has rather been laid on a few single features which have played a prominent part in recent developments or have appeared as specially characteristic of modern conditions. This will explain what might otherwise have seemed to be a lack of proportion in the space devoted to different branches of the industry.

Some apology may be due for the absence from this Report of any mention of several most important questions bearing on the subject in hand. It will be admitted, however, that any treatment of the problems of the trusts, organised labour, and railroad transport must, from want of space, have been necessarily inadequate; and it has seemed better to exclude them entirely.

The Report aims at something more than a description of works visited and of impressions received. In the first place, these have been constantly corrected by reference to the work of previous investigators, and acknowledgement must be made in particular to the Report of the delegation sent to the United States by the British Iron Trade

Association, which is embodied in the volume "American Industrial Conditions and Competition" (London, 1902); and to the two Reports of the Mosely Commissions. Dr. Hermann Levy's "Die Stahlindustrie der Vereinigten Staaten von Amerika" (Berlin, 1905) appeared too late to be largely drawn upon in the present Report. In the second place, conditions in America have been compared and contrasted, wherever possible, with those obtaining in our own industry. Where the two have differed sensibly, the attempt has been made to analyse the causes of such differences.

The pleasant duty remains of acknowledging the debt under which the author has been placed by the kind help of many who have assisted him in the course of his work. Among others, he specially desires to thank Dr. Hopkinson, the Vice-Chancellor of the University; Professor Chapman, under whose more immediate direction the work has been done; Mr. Alfred Mosely, C.M.G.; Mr. A. A. Stephenson, manager of the Standard Steel Works, Burnham, Pa.; Mr. James M. Swank, of Philadelphia, Secretary of the American Iron and Steel Association; Mr. Charles J. Forney, of Mount Holly Springs, Pa.; Mr. Samuel Groves, of Toronto; Hon. John Morrow, Superintendent of the Allegheny Public Schools; Hon. Carroll D. Wright, Commissioner of Labour for U.S.A.; Mr. E. D. Durand, of the U.S. Department of Commerce and Labour; the Brown Hoisting and Machinery Co., of Cleveland, Ohio; and the many managers and superintendents of plants who gave him facilities for seeing their works and supplied information in connection with their working.

FRANK POPPLEWELL.

THE GARTSIDE REPORTS.

THE Gartside Reports are the reports made by the Gartside Scholars at the University of Manchester. The Gartside Scholarships were established in 1902 for a limited period by John Henry Gartside, Esq., of Manchester. They are tenable for two years and about three are awarded each year. They are open to males of British nationality who at the date of the election shall be over the age of eighteen years and under the age of twenty-three years.

Every scholar must enter the University of Manchester for one Session for a course of study approved by the electors. The remainder of the time covered by the scholarship must be devoted to the examination of subjects bearing upon Commerce or Industry in Germany or Switzerland, or in the United States of America, or partly in one of the above-mentioned countries and partly in others, but the electors may on special grounds allow part of this period of the tenure of the Scholarship to be spent in study and travel in some other country or countries. It is intended that each scholar shall select some industry, or part of an industry, or some business, for examination and investigate this comparatively in the United Kingdom and abroad. The first year's work at the University of Manchester is designed to prepare the student for this investigation, and it partly takes the form of directed study, from publications and by direct investigation, of English conditions with regard to the industrial or commercial subjects upon which research will be made abroad in the second year of the scholarship. Finally each scholar must present a report upon the matters that he has had under examination. The reports will as a rule be published.

The value of a scholarship is about £80 a year for the time spent in England, £150 a year for time spent on the Continent of Europe, and about £250 a year for time spent in America.

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Iron and Steel Production in America

CHAPTER I.

The Metallurgy of Iron and Steel.

No account of the iron and steel industry, from whatever point of view, would be intelligible without a knowledge of the chemical and metallurgical principles underlying the production of the crude metal from its ores and its further working up into the various forms of finished products. A brief description of these fundamental principles will therefore serve as a useful introduction to, and basis for, the consideration of industrial conditions which is to follow.

Iron, as we know it in commerce, is not a chemical element, but a body of complex character whose constitution is still the subject of controversy. Not only is chemically pure iron obtained with great difficulty and at a correspondingly high cost, but its properties are such as to render it of little value in the industries. The commercial body, on the other hand, owes both its cheapness and its value in use to the presence of certain impurities, with one or more of which the pure metal is invariably alloyed. First among these, by the frequency of its presence and by the remarkable changes, which, even in small quantities, it effects in the character of the alloy, must be placed carbon.

Occurring almost as frequently, but with less influence on the properties of the product, are the elements silicon, manganese, sulphur and phosphorus.

The following elements are found as occasional constituents, and, generally speaking, only in steel of a special character, into which they have been introduced to confer

upon the metal some distinctive property, viz., nickel, chromium, antimony, tungsten, titanium, aluminium, arsenic, molybdenum.

The total amount of impurities in iron or steel often falls below one per cent., and only in rare cases exceeds nine or ten per cent. The effect of these impurities is thus seen to be out of all proportion to their quantity, a fact nowhere more strongly marked than in the case of the element carbon. Within a range bounded by carbon-contents of 0·05 per cent. and 1·5 per cent. respectively, this element alone can effect all the changes in character which are typified by soft, malleable, infusible wrought-iron on the one hand, and hard, brittle, fine-grained, easily fusible razor-steel on the other.

The influence of the other elements mentioned is scarcely less remarkable in the varieties of properties which they confer. Since the introduction of each new element will easily modify the effects of those already present, the metallurgy of iron and steel is largely a matter of so regulating the impurities in number and in quantity, as to ensure that combination of properties which is looked for in the finished product.

Carbon is effective not only according to the amount, but also according to the form in which it is present. When the carbon is in the free state as graphite, the iron is soft and brittle; when in the combined state, the iron is very hard and, within limits, of considerable tensile strength.

Depending upon its quantity and the form in which it is contained, carbon has been made the basis of a classification of iron and steel as follows:—

1. Cast iron containing 2·0 per cent. and upwards of carbon, the product of the blast furnace, which is known in three varieties:

(a) Grey cast iron, in which the carbon present is mostly in the form of graphite, rendering the iron

soft. This variety is employed in making iron castings and also for further conversion into steel.

(b) White cast iron, in which the carbon present is almost wholly in the combined state, giving a hard, brittle, very impure metal which finds its use as raw material for the production of wrought iron by the puddling process.

(c) Mottled iron, an intermediate variety, in which the carbon exists, partly as graphite and partly combined, giving a mottled appearance to the metal. Mottled iron is used chiefly in making iron castings either alone or mixed with grey iron.

Cast iron is comparatively easily fusible (1,100°–1,300°C.), but is incapable of being rolled or hammered.

2. Medium- and high-carbon steel, containing between 0·30 per cent. and 2·00 per cent. of carbon, much stronger and more ductile than cast iron, and possessing hardening properties. Except in exceptional cases, the carbon is wholly combined.

3. Malleable iron and steel, containing less than 0·30 per cent. of carbon, all in the combined form, which are further sub-divided into:

(a) Soft, mild, or low-carbon steel, when free from slag.

(b) Wrought iron, when containing slag.

Both these varieties are soft, ductile, malleable, weaker than high-carbon steels, yet stronger than cast irons, and possessing little hardening power.

Mild steel is very difficultly fusible, and wrought iron practically infusible.

Iron occurs but seldom in the free state in nature, and in quantities quite insufficient for use on a commercial scale. In a state of combination, on the other hand, the metal is one of the most widely diffused of the elements, and it becomes necessary therefore to free it from the chief impurities with which it is associated. The processes by which this is effected constitute the metallurgy of iron.

Iron Ores. The following are the chief varieties of iron ore, in the order of their comparative richness in iron, which can be successfully employed in the smelting of the metal:—

Magnetite, or magnetic iron ore, containing when pure up to 72 per cent. of iron. The chief deposits of this ore at present being worked occur in Scandinavia and in North America.

Hæmatite, oxide of iron, usually less pure than magnetite, and containing, at the best, not more than 70 per cent. of the metal. Large deposits of this ore are being worked in the Lake Superior region of North America and in Spain. It occurs in smaller quantities in Germany, and in this country in North Lancashire and Cumberland.

Brown iron ore, a hydrated oxide of iron of variable composition, but containing, from the presence of water, always less iron than hæmatite, on the average from 40—50 per cent. This ore is widely distributed, the largest deposits being the *Minette* fields of Lothringen, Luxemburg and Northern France.

Spathic iron ore, a compound of oxide of iron with carbonic acid, generally much less pure than the other ores. Associated with water, this ore constitutes the large Cleveland deposit in North Yorkshire, in which the iron seldom exceeds 32 or 33 per cent. In Germany this ore occurs in small, but widely distributed deposits, and is met with in England and Scotland as *clay-ironstone* and *blackband* respectively.

The carbonate ores, on heating to a moderate temperature, lose carbonic acid, and are oxidised at the same time to ferric oxide, the form in which iron occurs in hæmatite.

Smelting of Iron. "Every naturally-occurring form of iron being then a compound with oxygen, or easily convertible into such compound, the problem of smelting the ores resolves itself into the best method of removing their oxygen so as to leave behind the iron in a metallic state.

The process which has become almost universal, and the only one which will be considered here, consists in very strongly heating the ore in a furnace of special design—the blast-furnace—with coal, coke or charcoal fuel. The removal of the oxygen is not brought about to any great extent by the carbon in the state in which it exists in the fuel, but by carbonic oxide, a gas to which the fuel is burnt by the introduction into the furnace of large quantities of air. Carbonic oxide, being a powerful reducing agent, is further burnt, at the expense of the oxygen of the ores, to carbonic acid, in which form it leaves the furnace. Raised to a very high temperature by the chemical reactions occurring in the furnace, and having been deprived of its oxygen, the iron falls in a molten condition into a well at the bottom of the furnace known as the hearth.

But while the reduction of the ores to metallic iron by means of carbonic oxide represents the main course of the reaction in smelting, there occur at the same time a number of secondary changes which have an important bearing on the working of the furnace, and on the character of the metal produced.

In the first place, no ores are perfectly pure oxides; they contain invariably, in addition to the iron and oxygen combined together, more or less extraneous earthy matter or "gangue," which, being infusible, gives considerable trouble in its removal from the furnace. "Gangues" which are found associated with iron ores are generally of an acid nature, and the difficulty of their removal is overcome by adding to them some basic body which shall form a fusible compound at the high temperature of the furnace. Lime usually serves this purpose, less frequently dolomite. Such an addition is known as a "flux," and the fusible body produced by union of flux and gangue is "a slag."

The slag, being specifically lighter than the iron, floats

on the surface of the latter, and the two molten bodies are removed from the furnace and separated from one another by running them out through separate "tapping holes" in the hearth of the furnace.

It sometimes occurs that, by mixing different varieties of ore, one of an acid, the other of a basic nature, a self-fluxing material is obtained, and the addition of lime is obviated. This happens frequently in the case of the Minette ores of Luxemburg-Lorraine.

It has been mentioned that the fuel which finds employment in the smelting of iron ores in the blast-furnace is of three kinds—charcoal, coal, and coke. Of these, wood-charcoal is used in small and in diminishing quantities, owing to its scarcity, and not to any inherent defects of chemical properties, in which it has the advantage over coal and coke of great purity. Its use is confined to Austria-Hungary, Sweden, one or two districts of Germany and the State of Michigan in North America.

Coal is also yielding place to coke as a blast-furnace fuel, and in many cases where it is still retained is admixed with coke.

The chief requisites of a blast-furnace coke are: hardness combined with porosity; freedom from sulphur; and a high percentage of carbon which means a high calorific value and a low percentage of ash.

In addition to those already described, there remain to be mentioned as raw materials of the blast-furnace process certain by-products of the industry whose contents of iron or some other desirable element make their re-smelting, when employed to a limited degree, advantageous. Such are puddle-cinder, reheating-cinder, rolling-scale, hammer-scale and basic slag.

Before proceeding to a description of the blast-furnace and its mode of working, it will be convenient at this point to consider two of its most important accessories, the hot-blast and the hot-blast stoves.

In order to enable it to force its way through a sixty- or eighty-foot column of material consisting of coke, ore and flux, and also to intensify the reaction, the air requisite to burn the fuel to carbonic oxide is introduced into the furnace under a pressure which varies from five to twenty-five pounds per square inch in excess of atmospheric pressure. This compression is effected in large "blowing-engines," which in principle are simply double-bellows on a very large scale, the motive power being derived from steam or gas-engines. In either case the fuel providing the power is the waste gases which come from the blast-furnace, which contain about thirty per cent. of unburnt carbonic oxide and a few per cent. of hydrogen.

Also with object of effecting a more intense combustion of the fuel and of increasing the rapidity of the smelting, the air, after compression, is raised to a temperature of 800—1,200° C. before gaining access to the furnace. The waste gases of the furnace again serve the purpose of a fuel. The elevation of temperature is brought about in hot-blast stoves, tall cylindrical chambers lined inside with fire-brick and partially filled with an open-work arrangement of refractory material among and around which the furnace gases can burn. When the stoves have attained by this means to a maximum temperature, the supply of gas is turned off, and the blast from the blowing-engines on its way to the furnace is made to pass over the hot surface in the interior of the stove. While one hot-blast stove is thus yielding up its heat to the blast, a second is absorbing fresh supplies of heat from the furnace gases.

While the number of stoves required by each blast-furnace will necessarily depend on the size and rate of working of the latter, the quality of waste gases is, with rare exceptions, sufficient, and more than sufficient, for both production (*i.e.*, compression) and heating of the blast.

The Blast-Furnace. The blast-furnace consists of a

tall, narrow chamber, more or less cylindrical in form, whose walls are constructed of very refractory fire-brick, these being in some cases completely encased in a thin steel shell, in others strengthened by hoops of iron circling the walls at various points in its height.

A section of the interior of a blast-furnace exhibits a material divergence from the true cylinder, the sides tapering gently outwards at first, then more rapidly inwards, and ending in a cylindrical well or crucible at the base.

The well is pierced near the bottom by the metal tapping-hole, somewhat higher up by a slag tapping hole or "cinder-notch," and at the top by a number of tubes or "tuyeres" to carry in the hot blast, these latter being placed, to the number of from eight to sixteen, at equal distances apart round the circumference of the crucible. Since the combustion which takes place on the admission of the blast through the tuyeres renders the top of the well the hottest part of the furnace, the tuyeres are prevented from melting by artificial cooling. They are constructed of iron or bronze and are provided with double walls, between which a rapid stream of cold water circulates. The furnace is closed above by one, and in some cases two, bells, which, on lowering a short distance, give access to the furnace for the raw materials. The waste gases rise to the top and are led away through a brick-lined pipe to the stoves or boilers as they may be wanted.

When in blast, the furnace is filled with solid materials from within a few feet of the bell down to the level of the tuyeres. At this point the materials, already partly changed, are completely transformed into (1) molten iron which falls to the bottom of the well; (2) molten slag which floats on the iron; and (3) gases which rise through the materials in the stack until finally escaping at the top.

The process is continuous and uninterrupted, raw material being charged in from above and the iron and

slag run out from their respective tapping-holes at regular intervals of a few hours. Except on account of bad trade, a blast-furnace never cools from the moment it is "blown in" until the lining is worn out.

The chemical changes which occur are as follows:—Entering the furnace at about 900°C., when it comes into contact with white-hot fuel, the oxygen of the blast burns the latter to carbonic oxide, the real reducing agent of the blast-furnace process. The nitrogen undergoes no chemical change, but, in passing up through the column of material, transfers to this a considerable portion of the heat which is generated at the tuyere level. It then escapes along with the other gases, by way of the side tube or "downcomer" at the top.

The carbonic oxide, in its upward course, immediately reacts with hot oxide of iron, reducing the latter to the metallic state, and itself undergoing oxidation to carbonic acid. Further quantities of fuel reduce this carbonic acid to carbonic oxide, and so the oxide of iron becomes reduced, ultimately by the fuel, but immediately through the agency of carbonic acid.

This cycle of changes takes place continuously as the gases rise, until the temperature falls to 400°C., when all action ceases. Between 400° and 850°, however, the reduction of iron oxide is not immediately to the metal, but to another oxide (ferrous oxide), which is relatively richer in iron than the ferric oxide charged into the furnace. Complete removal of the oxygen is only effected from 900°C. upwards. If a carbonate ore is employed, it suffers at about 900° a decomposition into ferrous oxide and carbonic acid, and the former then reacts exactly as though an oxide ore had been used in the first instance.

This being the main process by which the metal is freed from its accompanying oxygen in the ore, it remains to be considered in what way the pure iron becomes alloyed with carbon, manganese, silicon, phosphorus and sulphur.

In contact with partially-reduced hot oxide of iron, carbonic oxide is decomposed with the deposition of carbon in a very fine form. This is gradually absorbed by the imperfectly reduced iron, finally becoming dissolved in the iron to the extent of about four per cent. An alloy of this composition has a relatively low melting point, and it is only after this impregnation by carbon that the metal becomes completely fluid.

Manganese occurs in iron ores in the form of a very difficultly reducible oxide. At temperatures employed in making the commoner varieties of pig, only about half the manganese undergoes reduction and enters the iron, the remainder being lost in the slag. Silicon is reduced from its oxide, in which form it is found in ores, by metallic iron itself at high temperatures, the amount of reduction being roughly in proportion to temperature. Thus with a hot-blast temperature of 1,100° C. an iron containing upwards of 3 per cent. of silicon is produced, while a temperature of 800° C. yields only about 1 per cent. of silicon in the pig.

But in addition to temperature, there is another factor which helps to determine the relative proportions in which these elements enter the slag and the iron respectively.

As already stated, a flux is added to the raw materials in the furnace charge to combine with the gangue or siliceous material (from which the purest ores are never quite free), and by forming a fusible slag, to allow of the removal of these impurities from the furnace in a convenient form. The reaction is the direct combination, at the high temperature of the furnace, of lime and silica to form a silicate of lime, which will be either acid or basic in character according as the silica or the lime predominates. If the lime added is insufficient to neutralise all the silica present, the excess of the latter will in all probability undergo reduction by iron, resulting in a high-silicon pig. On the other hand, with the conditions for the formation

of basic slag, *i.e.*, one in which the lime is in excess, the silica is more than accounted for by the lime, and consequently is only reduced by iron in small quantity. The case is reversed with respect to manganese, whose oxide is basic and combines with silica to form slags, in much the same way as lime does. Thus while a basic slag favours the production of a high-manganese iron, a silicious slag is a necessary accompaniment of a high-silicon pig. By adjusting in this way the proportions of flux and ore to one another with a full knowledge of their chemical composition, the quality of the resulting iron may be regulated to a considerable extent. The same thing holds true for sulphur. This is in every way an extremely undesirable element in iron, and since it is almost impossible to remove in the later stages of steel production, it is of the highest importance to obtain pig-iron as free from this element as possible. The only means of eliminating sulphur in the blast-furnace is in the form of sulphide of calcium through the slag, the necessary conditions being a basic slag and a high temperature.

In the case of phosphorus, temperature and character of slag are without appreciable effect, from 90 per cent. to the whole of the phosphorus present in the ore entering the iron. While phosphorus is on the whole an element of weakness rather than of strength in iron, a certain proportion of it is in some cases a decided advantage, as for example, in the manufacture of small castings. Moreover, this element allows of removal in the subsequent stages of steel manufacture, and up to a certain limit its value is then proportional to its quantity.

The chemistry of these five elements has been dwelt on at some length, since they are the determining factors, not only in the quality of the immediate products of the blast-furnace, but in the whole of the subsequent operations in the manufacture of steel, which is concerned simply and solely with the question of obtaining a product in which

these elements shall be contained in the form and to the extent which experience has decided to be best for any given purpose.

Of the products of the blast-furnace, the gases have already been referred to; the slag, for whose removal and working up several systems exist, will receive consideration at a later stage.

As mentioned at the beginning of the chapter, raw iron is distinguished as of two chief kinds; grey iron, whose carbon is mainly in the form of graphite; and white iron, in which the carbon exists in the combined state as iron carbide. The presence of manganese tends towards the formation of white iron, while that of silicon has an opposite effect.

But in addition to differences depending on the mode of existence of the carbon, the products of the blast-furnace are differentiated, according to their chemical composition, into puddle iron, forge iron, foundry iron, basic and Bessemer irons.

Foundry iron is the only raw product of the furnace which finds application without any further treatment other than re-melting, namely, in the production of iron castings.

The Purification of Iron. Every variety of blast-furnace iron contains, at best, a large amount of impurities, varying from 5—10 per cent. The further processes in the manufacture of steel are concerned with the partial or total elimination of some or all of these extraneous bodies, and the subsequent re-addition of those which are found to be advantageous.

The only methods in any considerable use to-day for the purification of crude iron are the puddling process, the acid and basic Bessemer processes, and the acid and basic open-hearth processes. Of these the first-named is rapidly diminishing in relative importance to the others, and a few words will suffice to describe its main features. The principle on which the process is based is the oxidation of

the impurities, in part by air, in part by oxide of iron; the carbon to carbonic oxide which burns and escapes, the other elements to their respective oxides, which together with the oxide of iron placed in the furnace for the purpose, form a fusible slag. This method of purification depends on the greater affinity of the eliminated elements for oxygen than for iron.

The Puddling Process. A puddling furnace is of the type known in metallurgy as "reverbatory." It consists of a grate for the combustion of coal to provide the necessary heat, and a closed hearth on which the actual operation takes place. The flames from the fire drawn across the hearth are reflected downwards from the low roof of the latter and finally pass out into the flue which creates the draught. The whole is built of refractory material in order to withstand the temperature of molten iron and the hearth in addition is lined with a slag rich in iron oxide. This not only preserves the bed of the furnace from corrosion by hot metal, but takes part in the reaction as one of the oxidising agents of the impurities. During the melting down of the pig iron, a good deal of silicon is removed by direct oxidation by the air. As soon as the metal has come to the molten condition the temperature is lowered by partially closing the dampers of the flue, and the iron then intimately mixed with the oxide of the hearth by means of a long iron rod worked by hand. No successful mechanical puddler has yet been devised. The chemical reactions already described take place, the slag runs off in a thin stream, and the iron becoming purer and purer gradually loses its fluidity and is removed from the furnace in a pasty mass. Enmeshed in this mass is a certain quantity of slag which is only partially squeezed out by hammering. With this exception, the product "wrought iron" is almost free from impurities, containing more than 99 per cent. of metallic iron. When finished by simple rolling the product is known as "puddled bar."

To improve its mechanical properties, puddled bar may be cut up into short lengths, re-heated in piles of several bars, and finally re-rolled. It is then known as "merchant bar."

As raw material for the puddling process white iron is preferable to grey, its comparative freedom from silicon reducing the time required for its purification. On the other hand, since the silicon in pig-iron reduces more than its own weight of iron, close-grained grey iron has come into extensive use in what is known in America as "pig-boiling."

Conversion into Steel. There are two general methods in use for the conversion of pig iron into steel, requiring correspondingly different types of furnace.

In the Bessemer process the iron is completely deprived of its impurities, attaining thereby the composition of wrought iron; the elements still wanting to produce the physical properties demanded are then re-introduced in the form of ferro-silicon or ferro-manganese, alloys of iron with silicon and manganese respectively, which are rich in carbon but free from sulphur and phosphorus.

In the Open-Hearth process the purification takes place more slowly and is under better control. It is stopped when the proportions of certain elements have reached the limits required, and the necessary re-additions are smaller than in the Bessemer process.

The removal of the impurities is effected in both cases by their oxidation and conversion into a slag by the addition of a flux, just as in the blast-furnace process.

Bessemer Process. In the Bessemer process this oxidation is effected by blowing air through cast iron in the molten condition, the heat developed in the combustion of the carbon, silicon and manganese being more than sufficient to retain the metal in a fluid state until the end of the reaction.

The Bessemer converter consists of a brick-lined iron vessel, having the form of an inverted crucible, which is

capable of being turned on a horizontal axis to admit of charging and discharging the iron through an opening at the top of the vessel. The metal comes directly from the blast-furnace or from a mixer of blast-furnace iron, where the product of several furnaces is equalled in composition. The air blast enters through a number of small holes in the bottom of the converter, forces its way in many streams through the molten metal, and the combustible gases formed burn with an intense flame at the mouth of the vessel.

The period of oxidation varies, with the quantity and character of the metal, from ten to twenty minutes and is determined by the appearance of the issuing flames.

As soon as the "blow" is over, the calculated quantities of ferro-manganese and ferro-silicon are added to the converter either solid or molten, and after a short interval to allow of complete mixture, the whole contents of the converter are poured into an iron ladle in which the slag floats on top of the iron. The latter is run out through the bottom of the ladle into "ingot moulds," and after solidifying is ready to be either hammered or rolled.

The reactions of oxidation proceed in the following manner:—The silicon is most rapidly oxidised, and the silica formed combines to a slag of ferrous silicate with some ferrous oxide simultaneously produced. The manganese undergoes an exactly analogous change but more slowly. The carbon only begins to oxidise rapidly when most of the silicon and manganese have been removed, and then escapes and burns, mostly in the form of carbonic oxide. Until their removal has been completed, the impurities retard any considerable oxidation of iron, but this change ensues with great rapidity as soon as the last portions of carbon are burnt off. The blowing is stopped before this can take place. The greater part of the heat developed in the process results from the oxidation of the silicon, a certain minimum of which element is

therefore required in the raw iron if cooling in the converter is to be avoided. This minimum would appear to be about 0·9 per cent. of silicon, but depends of course on the quantities of carbon and manganese present, both of which elements are heat producers in a less degree than silicon.

The addition of ferro-manganese to the purified charge has three results: it effects recarburisation; the manganese reduces any oxide of iron which may have been formed and which prevents the proper working of the steel in the later stages; and the same element changes the sulphur present into the least dangerous form in which it can occur.

In the process as described, an acid or silicious lining is used in the converter and no sulphur or phosphorus is removed from the iron during conversion. The raw material for the acid Bessemer process must contain therefore not more than 0·10 per cent. of phosphorus nor more than 0·05 per cent. of sulphur.

Unfortunately, the greater part of the world's supplies of ore are not such as to give an iron sufficiently low in phosphorus for successful conversion by the Bessemer process. It became necessary then so to modify the process of conversion, if possible, as to allow of the removal of phosphorus along with the other impurities, and the change was successfully effected in 1878 by Thomas and Gilchrist.

The condition for the removal of phosphorus is the formation of a basic slag which will take up the oxidised phosphorus just as in the puddling process. Such a slag is only stable in the absence of acid or silicious bodies, and the lining of the converter must therefore be of a basic character. The process of Thomas and Gilchrist has thus come to be known as the basic Bessemer, or simply, the basic process.

With the exception of this difference in the character of the lining, the converters and the methods of working are

not essentially different in the two processes. Silicon, manganese and carbon are removed as before, and in the same order, and the phosphorus forms a slag of phosphate of lime with the flux which is introduced for the purpose. But in addition to that required for fluxing the phosphorus, sufficient lime must be present to remove the silica as silicate of lime, otherwise this acid body will prevent the formation of the basic slag of phosphorus. The dephosphorisation will therefore be greatly facilitated by the absence of silicon in the iron, and this element should not in general exceed one-half of one per cent. More than one per cent. of silicon successfully prevents the removal of phosphorus. But since the greater part of the heat required was derived in the acid process from the silicon, this element must be replaced in the raw material for the basic converter by some other heat producer. This function is fulfilled by the phosphorus itself, and its presence up to the extent of as much as two or three per cent. is a distinct advantage, and up to about 1·5 per cent. an absolute necessity. The removal of sulphur in the basic process is very erratic, but since the conditions determining even a partial desulphurisation are not understood, the permissible limit of this element in the iron is, as before, low.

The Open-Hearth Process. The second general method for the conversion of iron into steel combines the principles of both puddling and Bessemerising, *i.e.*, it is an oxidation by both solid and gaseous bodies. In addition, it is to some extent merely a mixing process, crude high-carbon iron and steel-scrap being melted up together to produce a steel of intermediate properties. The extent to which these three processes take place in the open-hearth furnace will depend on the relative proportions and the composition of the raw materials available and on the quality of product to be obtained.

The essential point in which the open-hearth process differs from the one previously described is that it is

independent of an internal source of heat, with the result that from this point of view the composition of the raw materials is of little moment. The metal in the furnace is kept molten through the agency of combustible gases from an external source, and all that claims attention in the selection of the raw materials is a proper regard for the final composition.

The process can be carried out, like the Bessemer, on either an acid or a basic hearth, non-phosphoric or phosphoric pig-iron being used accordingly. The reactions are similar in the two cases to the corresponding changes in the Bessemer converter, namely, the formation of a silicious or a basic slag containing the impurities. In the acid process, no trace of either sulphur or phosphorus is removed and the percentages of these elements in the finished steel are therefore somewhat higher than in the original materials, through total loss of weight during purification. A pig-iron containing 0·05 per cent. of phosphorus and of sulphur cannot be depended on to yield a product with less than 0·06 per cent. of each of these elements.

On a basic hearth no difficulty is experienced in removing the phosphorus by additions of lime to form a stable slag, provided that the phosphorus-content of the pig-iron is not too high compared with that of the carbon. The boiling of the charge which the removal of the latter element in the form of carbonic oxide maintains, would appear to be necessary to bring the phosphorus into contact with the slag and effect its removal, and when the boiling ceases, any phosphorus remaining in the bath is eliminated with great difficulty. It is safest to employ only a medium-phosphorus pig, and indeed very low phosphorus iron can be successfully worked in a furnace of this type, in which respect the open-hearth process differs from the Bessemer, where a certain minimum of the element under consideration is a *sine qua non* of the thermal system.

With respect to sulphur, its removal is as variable as in the former process, and the only safe course is to employ low-sulphur raw materials, although in the present case several more or less successful methods are in use for the removal of the element from the finished metal outside the furnace.

In construction, the open-hearth furnace is of the reverbatory type, not unlike the puddling furnace in principle, though differing from the latter very materially in appearance and details. The hearth is built of refractory material lying on a framework of iron plates and is entirely closed in by sides, ends and roof of the same material. The only difference in construction between basic and acid furnaces lies in the material with which the bottom and sides of the hearth are further protected from the corroding action of metal and slag. For the treatment of phosphoric materials this consists of burnt dolomite; for non-phosphoric materials, of sand.

The furnace is provided at either end with a pair of port-holes, one above the other. Through one set there enter the combustible gases (which are produced in generators away from the furnaces), together with air, and these, having been burnt during their passage across the hearth, leave by way of the second set of ports. In a furnace of this type, which may vary from five to fifty tons in capacity, it is not easy to keep a large quantity of iron in a molten condition, and the difficulty is increased when it becomes necessary to melt down metal which is charged cold into the furnace. The brothers Siemens overcame the difficulty by the invention of the regenerator system, by which the greater part of the waste heat of the furnace is utilised afresh.

The waste gases on leaving the furnace pass through two chambers filled with a chequer-work of fire-bricks, to which they impart a large quantity of their heat. After the chequer-work has attained a maximum temperature,

the direction of the gases through the furnaces is reversed, so that the fresh gases and air now enter through the second set of ports, having first passed over the hot brickwork and become considerably enhanced in temperature thereby. The waste gases now pass through a second pair of "regenerators," heating them up as before. By alternating the direction of the gases through the furnace at regular intervals, the regenerators are successively heated up by the waste gases and cooled by the incoming gases, with the result that a much higher temperature is attained in the furnace than would otherwise be possible.

The raw materials are usually charged cold and they most often take the form of pig-iron and scrap steel. The latter dilutes the impurities of the pig and both at the same time undergo oxidation by the gases. When for any reason the carbon in the bath is not reduced sufficiently, or sufficiently fast, a little iron-ore is thrown in to bring about the desired effect. If, on the other hand, the carbon has been too completely removed, the addition of a little pig-iron brings both back to the right composition. The melting is generally continued until the carbon reaches the right point, and additions of ferro-manganese and ferro-silicon then made in the proportions desired.

The charge is removed through a tapping-hole on the side of the furnace remote from the charging-doors. During melting, the hole is kept sealed up with clay, which is easily removed when the steel is ready. Steel and slag run into the ladle together, the latter floating on the top, and the two are separated by tapping the metal into moulds through the bottom of the ladle.

Crucible Steel Process. A third method of steel production, which owes its importance to the value of the output in proportion to its weight, must here be shortly considered.

The crucible steel process differs *in toto* from those just described.

In the English process, as practised in Sheffield, the first raw material is what is known as Swedish bar iron, that is, wrought-iron produced by the puddling of Swedish charcoal pig-iron in a Swedish-Lancashire hearth furnace. Only the purest ores are used in its manufacture, and it is characterised by its freedom from impurities, especially phosphorus and sulphur. A typical analysis of Swedish bar is:

Carbon	0·050%
Silicon	0·037%
Sulphur	0·006%
Phosphorus	0·012%
Manganese	0·108%

The first process which the Swedish bar undergoes in this country is "cementation." This consists in heating the bars in contact with wood charcoal for a considerable time until the carbon impregnates the iron and attains a percentage of from 0·5 to 2. Cemented bars are graded according to their average carbon contents. The carbon is, however, far from being evenly distributed through the bar, the outside being the most highly carburised, while the interior may be almost unconverted.

The final process consists in re-melting in the crucible. Crucible melting has several functions. Swedish bar, whether cemented or not, always contains, from the manner of its production, a certain amount of slag, and this must be removed before the steel can be made up into the cutlery, tools or castings for which it is designed. The only opportunity for complete separation of slag from steel in the crucible steel process is at the final stage. Again, melting in the crucible brings about homogeneity with respect to carbon contents, of the cemented bars melted.

Finally, this process allows of the production of special steels containing manganese, molybdenum, chromium, tungsten, etc., by melting up together the iron alloys of these metals and either cemented or uncemented bars.

CHAPTER II.

General Considerations.

In the present chapter the attempt will be made to present an account of the broad characteristics of the American iron and steel industry considered as a whole and from an external point of view. Such a presentation will have reference to the extent, the location and the general metallurgical character of the industry, and to other features in which it may resemble or differ from the same industry in other countries.

In later chapters the discussion will be extended to the internal organisation of the industry, the interdependence of its several branches, a description of technical processes and of actual working conditions, and the organisation of individual plants.

Two very striking features of the American industry, features which have aroused considerable comment in this country, are its recent rapid growth and its present extent.

Some idea of the latter may be gained from a consideration of the statistics of production of pig-iron and steel in the two years 1902 and 1903, the figures for Germany and Great Britain being inserted for comparison. It must be borne in mind, however, that nothing more than a rough comparison is to be obtained from such figures, since the productions in any one year may be greatly influenced by temporary causes, showing thereby a wide departure from the normal tendency of the industry.

Production of Pig-Iron in the United States, Germany (including Luxemburg) and Great Britain during the Years 1902 and 1903 (in gross tons of 2,240 lbs.).

	1902.		1903.
U.S.A.	17,821,307	...	18,009,256
Germany ...	8,234,607	...	9,883,921
Great Britain...	8,586,693	...	8,811,204

Production of Steel in the United States, Germany and Great Britain during the Years 1902 and 1903 (in gross tons of 2,240 lbs.).

	1902.		1903.
U.S.A.	14,947,250	...	14,534,978
Germany ...	7,625,068	...	7,858,495
Great Britain...	5,022,067	...	5,134,101

America's position with respect to both iron and steel production is thus seen to be supreme. Of the estimated world's output of these metals in 1900, America was responsible for more than one-third.

A short review of the progress by which such a position has been attained exhibits the rapid character of the development in the United States. As Levasseur points out, "the production of pig-iron has doubled almost every tenth year during the last fifty years." The increase in steel production has been none the less marked, though concentrated largely into the last ten or fifteen years.

A glance at the accompanying figure will reveal the irregularity of the American development and at the same time the comparative freedom from fluctuations in the cases of Germany and Great Britain. The phenomenon of the periodic cycles in trade can be distinctly read in the history of the American iron and steel industry at intervals of ten years.

The three facts of a rapid development, periodic temporary sets-back, and a present large production are

not without an important influence on the character of the industry, and will be found to differentiate it from those in which the increase has been more gradual, as in England, more regular, as in Germany, or the present scale of production more limited, as in both these countries.

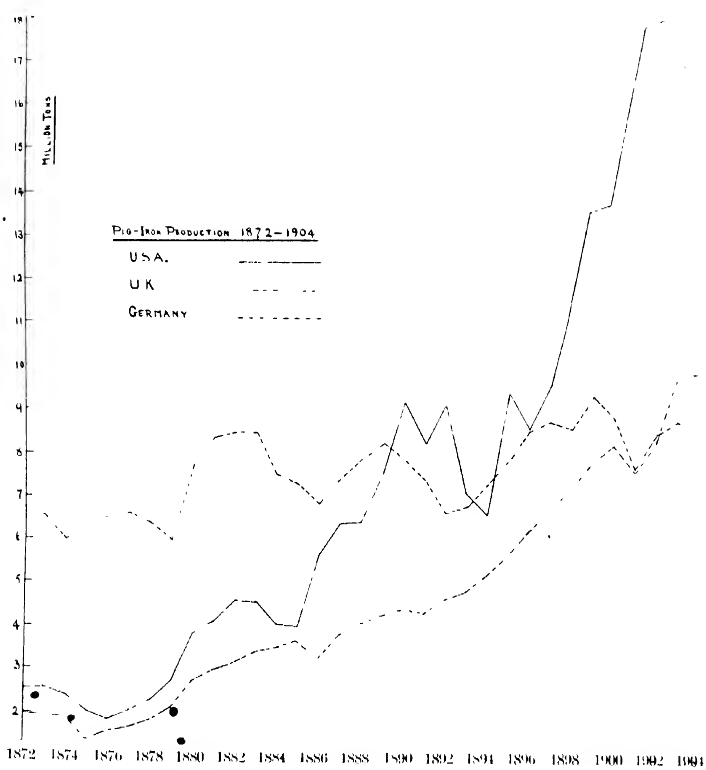
Firstly, as to the rapidity of development. Whatever may have been the causes, and many are those which have been assigned, this phenomenon has enabled the American industry to a greater degree than any other, to take advantage of previous experience and to incorporate, at each step, the methods and apparatus of well-proved efficiency for economic production. Each new plant that is erected is an epitome of the latest practice in its own particular field.

But rapid growth has done more than this. It has been an incentive to experiment. New methods require new forms of apparatus, and receive greater encouragement where the expansion of the industry is a rapid one.

Lastly, a development of this character not only allows of, and is an incentive to, progress, but demands it. Each new plant added raises the average efficiency of the whole industry, and the more rapid the expansion, the more quickly do the older plants fall out of date and require modification or renewal if they are to enter into successful competition.

Here we see the effects of the large fluctuations to which the American industry has been subject. In a country of slow and regular progress, old and out-of-date plants and methods die hard. They exist probably—to use a physical simile—in a kind of super-cooled condition for a considerable time after their freezing-out point has been passed, the sudden shaking-up of things which is required for their removal never taking place in such an industry.

In America, either such super-cooling is rendered impossible by the great mobility and the freedom for the natural action of economic laws, which is the characteristic


Pig-Iron Production 1872–1904
U.S.A.
U.K.
Germany
Million Tons
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1872 1874 1876 1878 1880 1882 1884 1886 1888 1890 1892 1894 1896 1898 1900 1902 1904

of that country, or else super-cooling is arrested, before it has proceeded far, by the phenomenon of periodic cycles in trade. In times of great booms, the supply always lags behind the demand, and a large increase in productive capacity takes place. On the return of more normal times, this capacity must be reduced, and the plants put out of action are, not those just added, but the oldest and least efficient. In this way there is a screwing up in efficiency both of the "marginal" plants and of the whole industry.

The natural outcome of such rapid expansion is the present large scale of production; and this we find accompanied by an increase in the size of the industrial unit. Whether judged by number of employees, output of product, or by the producing capacity of the plant, there is no doubt that the average works is much larger in America than elsewhere. And this result has been attained by development in organisation in two directions, specialisation and integration.

The economies to be derived from specialisation have been partly the cause and partly the outcome of the rapid expansion of the industry. They are those of material, of labour, of superintendence, and, especially in the case under discussion, of the possibility of a large use of labour-saving machinery; and all are to be found in the many works devoted to the large-scale production of a single article.

Typical works of this character are the Howard Axle Plant in Pittsburg, the various car-wheel works in Pittsburg and elsewhere, and the plate-rolling works of the Lukens Iron and Steel Company and of Worth Brothers at Coatesville, Pennsylvania.

In each of these works only a single product is turned out, and generally by a few simple operations. Each works becomes practically a machine, and a machine of a simple character.

But development of specialisation in production has not

been confined to any small number of works, although it is exhibited in a high degree by those mentioned. It runs through almost every branch of the iron and steel industry, and is nowhere more evident than in the extent to which labour-saving machinery has been developed and receives general employment in American works. At this point it is only necessary just to mention the skip-hoist for blast-furnace charging, the ore-bridge for handling iron-ore, the Wellman charging-machine, the continuous rolling-mill, and the pig-casting machine, as examples of the chief triumphs in labour-saving devices.

The next step in organisation is the integration of a number of specialised processes either into a single works, or under a single management. Integration may have two purposes. Its object may be, on the one hand, the saving in transportation of material between two consecutive operations; independence of external markets for the raw materials of the various processes; the desire to employ the by-products of one process as the raw material of another; and the possibility of so balancing the various processes as to obtain the most productive arrangement.

Such integration results in works like Jones and Laughlin's, in Pittsburg, the Cambria Steel Works, Johnstown, and many others which turn out every variety of finished product.

The object of integration may be, on the other hand, a controlling interest in an industry or in one or more branches of it, together with the power of regulating output and prices. It is on a larger scale than is possible by the mere expansion of a single works. It is the integration under one management of a large number of units of production. The advantages, in addition to those already described, are working with a single profit, centralisation in buying and selling, saving in expenses of advertising and other smaller economies.

Such organisation is typified by the United States Steel Corporation. It is a Trust which seeks something more than the economies of large scale production and the advantages of integration. By aiming to control the market, it is a deliberate attempt at monopoly organisation. We are not here more concerned with the Trust than to mention it as a factor, and a not unimportant factor, in the present organisation of the American iron and steel industry. The whole question of Trusts is too large to be entered into in the present essay.

Concurrently with the development in actual manufacturing processes and in the scale of production, there has necessarily occurred an expansion in those branches of the industry which are concerned with the production of the raw materials.

In the case of fuel, or rather of coke fuel, this has meant little more than a multiplication of the number of plants and a consolidation of many of them under a single control. In no other part of the industry has increased production exerted so slight an influence on the methods employed, or brought about so little specialisation. The present movement in the direction of more economical coking processes is quite independent of the extent of the industry.

The ore industry, on the other hand, has undergone a remarkable development in the last twenty years, not only in extent, but in method of organisation, particularly organisation of transport.

As the local ores of Pennsylvania and the East gradually fell in quality, and began to show signs of exhaustion, it became necessary to tap new sources of supply of better grade ores. Such an ore was found in the large deposits of Michigan, Minnesota and Wisconsin around the shores of Lake Superior—what is known as the Lake Superior region—in great quantities and of a high degree of purity and richness. This latter fact gave a great impetus to

the development of the "Superior" ores, since in a country where ore and fuel are separated by enormous distances, freedom from worthless matter is of the utmost importance in a material whose cost is largely one of transportation.

While this industry rapidly developed, then, every effort was put forth to render the transportation of the ore from mine in Minnesota to furnace in Pennsylvania—an average distance of a thousand miles—as efficient and economical as possible.

The difficulty of the problem—a problem of mining the ore, transferring from mine to Lake port by rail, from Lake port down the lakes by steamer, and from lower Lake port to furnace by rail, including thus a double trans-shipment en route—allowed of no half measures. The extent of the traffic has allowed of large expenditure on labour-saving machinery, and a most successful solution of the problem has been provided.

In no other branch of the industry has development been more rapid or more attributable to the use of labour-saving devices, and it would be difficult to find another case which so well exhibits the influence of progress on cost of production.

The location of the American industry is traceable ultimately to that of the raw materials for pig iron production. The economy arising from a direct conversion of iron into steel in the molten condition as it comes from the blast-furnace is bringing about the establishment of blast-furnaces and steel works in single plants. With rare exceptions, steel plants are independent of outside sources of supply for their principal raw material pig-iron.

Other factors which have been mentioned as determining the location of the industry are labour and markets. But it must be remembered that in the United States a new industrial establishment creates its own supply of labour much more readily than in older countries where the

mobility of labour is less developed. The recent removal of the American Bridge Company's works from Pencoyd, near Philadelphia, to Ambridge, some five hundred miles distant, saw the transference of some hundreds of workmen from one place to the other without any difficulty.

Again, the market for iron and steel products is as wide as the country itself, and no locality possesses an exceptional advantage in this respect over any other.[1]

Accordingly we find the situation of the fuel and ore supplies, and the means available for their transportation, the determining factors in the location of the industry.

Iron and steel production in the United States can be referred broadly to three districts. The first of these must be taken to include Pittsburg and that part of Pennsylvania which lies west of the Alleghanies, Ohio, West Virginia, Chicago and the works along the shore of Lake Erie as far as Buffalo. The furnaces in this district are dependent upon Lake Superior ore supplies, and on the Connelsville and Pocahontas coking fields for fuel. While, on the one hand, more ore than coke is required to produce a ton of iron, the fuel is more difficult, and therefore more costly to transport, and accordingly we find the industry situated between the two. It is at present, and will probably remain, nearer the coke, and chiefly at Pittsburg, for the reason that Pittsburg had already become something of a centre and market for iron before the large development of the Lake ores; and these advantages, together with a very cheap supply of natural gas and a skilled labour market had not been offset before the remarkable system of transporting the Lake ores was established. At the same time, many new plants are being placed on the Lake front where the

1. An exception must be made to this statement in the case of certain works which have been placed on tide-water with the express purpose of producing for export. But even in this case, the market is not the only determinant, such works being mainly dependent on foreign ore supplies, for which their situation is exceptionally favourable.

ores can be shipped directly from boat to furnace, thus saving train freight and trans-shipment. There is probably a zone of considerable size lying intermediate between ore and fuel supplies, in which the cost of production with respect to hauling raw materials and hauling away product to market is a minimum. The Lake front appears to be within this zone.

The second district is the South, really two districts in Alabama and Tennessee respectively, characterised by close proximity to ore and coal, both, however, of inferior quality to those of the North, and by a cheap, if not economical, supply of black labour. The cost of production of foundry iron is undoubtedly less in the South than in the Mahoning and Shenango valleys near Pittsburg. In the Pittsburg market this advantage is offset by the greater freight on the former, and prices generally balance. The industry in the South is largely concerned with the production of foundry irons, although several large steel works exist. These, however, are under a disability by reason of their distance from large markets, from which their favourable situation for an exporting trade hardly relieves them. The southern industry is very much smaller than that of Pittsburg.

The third district is still less strictly defined than the first. It refers to all those furnaces which are situated east of the Alleghany mountains, and may for short be termed the East. The majority of the furnaces of Eastern Pennsylvania lying in the Lehigh Valley, and stretching from Allantown to Harrisburg, were built originally to smelt local ores with anthracite coal from the neighbouring coalfield. For reasons which will be discussed later, anthracite gave way to coke as a fuel, and the local supplies of ore often became worked out. The majority of these furnaces are now, therefore, largely dependent upon Lake ores, and upon coke from Altoona or Connelsville. The only advantages which the district possesses are a good

supply of steady labour and proximity to eastern markets.

On the other hand, there exist in the East a small number of very efficient up-to-date furnaces, built for the most part quite recently, and working on newly-developed local ore-supplies of good quality; and the economic position of these plants is very different from that of those just described. Such are the furnaces at Wharton, N.J., at Port Henry, N.Y., and at Cornwall, Pa.

The metallurgical character of an iron and steel industry is determined to a very great extent by the quality of the ores available, and particularly by the composition of the ores in respect of the two elements sulphur and phosphorus. It has already been stated in a previous chapter that while practically the whole of the phosphorus in an ore finds its way into the pig-iron in the blast- furnace process, the percentage of sulphur in the product can be largely controlled by the mode of working the furnace.

The reverse is the case in the steel furnace. Here the sulphur is a fixed quantity, while the phosphorus can be almost entirely eliminated by employing a basic lining.

In the open-hearth process, the necessary heat is derived from an external source, and the raw material is selected purely with a view to the final composition. Where an ore low in sulphur and phosphorus has been available, the pig-iron is converted in an acid furnace, while for a high-phosphorus pig-iron, a basic lining is employed.

In the Bessemer process, on the other hand, not only the final composition of the steel, but also the initial contents of the pig-iron must be taken into account, since here the heat necessary to maintain the metal in a molten condition during conversion is derived from the burning out of the impurities themselves. With a basic lining, the use of silicon for this purpose is out of the question, since it would combine with the lining and prevent the removal of the phosphorus. Practically the whole of the heat required must therefore come from the phosphorus, a

percentage of not less than 1·80 per cent. of which is essential in the pig-iron for the basic Bessemer process. Ores rich enough in phosphorus to produce such an iron are not available in America, and the basic Bessemer process is unknown.

For the acid Bessemer process, the pig-iron should not exceed 0·10 per cent. in phosphorus-contents.

The wealth of American iron ores consists principally of those available for acid-Bessemer or basic-open-hearth smelting, and accordingly we find these two methods in large preponderance. But as the better class of ores, which alone are available for the Bessemer process, is being gradually worked out, the open-hearth process is coming more and more into prominence. These facts are exhibited by the following figures showing the production of steel by various processes in the year 1903.

PRODUCTION OF STEEL IN THE UNITED STATES, ACCORDING TO PROCESSES, IN THE YEAR 1903, IN GROSS TONS.[1]

	Acid.	Basic.	Total.
Bessemer	8,592,829	—	8,592,829
Open-Hearth... ...	1,094,998	4,734,913	5,829,911
Crucible and Miscellaneous	112,238	—	112,238
			14,534,978

Rails are made exclusively of Bessemer steel, plates exclusively of open-hearth steel, and structural material generally, of both kinds.

Acid open-hearth steel is employed for a limited class of work requiring a high quality of material which would otherwise be obtained by the crucible process. Such work includes armour plates, steel castings, car wheels, axles and shafting.

1. American Iron and Steel Association Annual Report, 1904.

Although crucible steel figures so small in the above tables, this branch of the industry is a highly specialised one, and both in respect of number of workmen employed and of value of product, is much more important in proportion to quantity of output than any other branch of the industry.

CHAPTER III.

Raw Materials.

1. *Fuel.* The various kinds of fuel employed in the production of iron and steel in America are:—

Natural Gas.
Bituminous Coal.
Anthracite.
Coke.
Charcoal.

Of these, the first-named material is used only for soaking-pits and reheating-furnaces, and for melting steel in open-hearth and crucible-furnaces. It finds no application in the production of iron in the blast furnace. The employment of natural gas is confined to a comparatively small area in the Middle West where it is found, although this area includes the very important centre of Pittsburg. The production of natural gas in 1903 was estimated at 238,769,067,000 cubic feet. In the matter of its distribution, Pennsylvania leads all other States, consuming nearly one-half the entire production. Indiana is second and Ohio and West Virginia respectively third and fourth.

The gas is carried long distances through pipes varying from ten to twenty inches in diameter; in one case no less than 200 miles, from Lewis County, in Central West Virginia, to Toledo, Ohio.

Pittsburg is completely equipped with natural gas for both domestic and trade consumption. The distribution is for the most part in the hands of private companies, who charge a price of 37 cents per 1,000 cubic feet to householders, while iron and steel establishments obtain the same quantity for the low sum of 20 cents. In some cases, however, works own their own supplies, in which case they are at an even greater advantage.

Wherever possible, natural gas, by reason of its cheapness, takes the place of artificial gas for smelting purposes. Its use obviates the building of plant for the production of "producer gas," thus saving space, and it also allows more perfect control over the temperature of the furnace in which it is employed. This is an important advantage to the steel-smelter, to whom a single bad "gasman" on a producer will often cause endless trouble.

Moreover, an open-hearth furnace employing natural gas as a fuel is built without regenerators, whereby not only in initial cost, but, what is more important, in repairs, a considerable saving is effected. For heating boilers, natural gas is a less economical fuel than coal, and it finds little or no application to this purpose.

The relative compositions of natural and producer gas are:—

	Natural Gas.	Producer Gas.
Marsh Gas	67% ...	1%
Hydrogen	22% ...	29%
Ethylic Anhydride ...	5% ...	—
Nitrogen	3% ...	42%
Ethyline	1% ...	—
Oxygen	trace ...	—
Carbonic Oxide	trace ...	22%
Carbonic Acid	trace ...	6%

The Calorific Power of Natural Gas is 789, of Producer Gas 164. In other words, the flame of natural-gas is about five times as hot as that of producer-gas.

In the matter of coal, America has a practically inexhaustible supply, and is independent of foreign sources. Less than 1 per cent. of the total consumption of coal in 1900 was imported, while three times this quantity was exported.

The total production in 1903 was distributed between the two kinds—bituminous and anthracite—as follows:—[1]

Bituminous	252,454,775 gross tons.
Anthracite	66,613,454 " "
Total	319,068,229 " "

Both kinds of coal are employed in the raw state in the blast-furnace, but to a comparatively small, and, in the case of anthracite, diminishing extent. By far the greater quantity of iron is now smelted by coke alone.

"Until 1840 all the pig-iron in America was made with charcoal. From 1840 on, anthracite was used, and in 1850 it had become usual to smelt with coke and bituminous coal."[2]

Writing in 1890, Sir Lowthian Bell said: ". . . . . furnaces in the Lehigh Valley and others lying convenient for getting anthracite were using it almost exclusively upon the occasion of my visits in 1874 and 1876. Since then, the make of the furnaces has been greatly increased, and for this the splintering property of anthracite is so inconvenient that the use has been greatly reduced in recent years, in point of quantity." The following table gives the weights of pig-iron made in the United States with different kinds of fuel for a period of years.

1. American Iron and Steel Association Annual Report, 1904.

2. Levasseur—"The American Workman".

Production of Pig Iron in U.S.A. According to Fuel Used.[1]

(Long Tons.)

Fuel used.	1896.	1899.	1901.	1903.
Bituminous, chiefly coke	7,166,471	11,736,385	13,782,386	15,592,221
Anthracite and coke	1,034,745	1,558,521	1,668,808	1,864.199
Anthracite alone	111,667	41,031	43,719	47,148
Charcoal	310,224	284,766	360,147	504,757
Charcoal and coke	—	—	23,294	927

The reason for the employment of coke as a blast-furnace fuel, to the exclusion of anthracite, lies in the physical rather than the chemical properties of the fuel. Indeed, chemically speaking, anthracite coal is quite as pure, if not purer, than the best coke, as the following analyses show:—

	Anthracite.	Connelsville Coke.
Fixed Carbon	88%	87%
Ash	7%	10%
Sulphur	0·68%	0·90%
Phosphorus	0·003%	0·10%

As a blast-furnace fuel, however, anthracite burns more slowly than coke. The additional disadvantage of splintering in the furnace has been already referred to. For these reasons its use in the blast-furnace has been largely contracted during recent years, particularly in the East, whose furnaces were favourably situated with regard to the supply of this fuel from the beds of Eastern Pennsylvania.

Raw bituminous coal is a much less pure form of fuel than anthracite or coke, Connelsville bituminous coal analysing as follows:—

	Connelsville Coal.
Fixed Carbon	60%
Volatile Matter	32%
Phosphorus	0·03%
Sulphur	1·00%
Ash	6–7%

1. U.S. Geol. Survey, Mineral Resources, 1903.

The disadvantages of such a fuel in the blast-furnace are that, in proportion to calorific power, it requires a much greater space than coke, and that, since it has practically to undergo coking in the furnace before it acts as a fuel, a much greater time is required to smelt by its means. The blast-furnace becomes under these conditions a combination of coking-oven and blast-furnace, its efficiency as an iron smelter being thereby reduced.

Bituminous coal is frequently employed admixed with a much larger quantity of coke. Under these conditions most of the disadvantages of the former fuel disappear, and at the same time a blast-furnace gas rich in combustible matter is obtained.

Of the large beds of bituminous coal which America possesses, only a limited number are available for the manufacture of coke. In addition to freedom from sulphur, the coal must possess the peculiar property of caking when heated, in order to produce a good hard coke. Such coal is found chiefly in the Connelsville region of Pennsylvania and the Pocohontas region of West Virginia. To a less extent and of an inferior quality, coking coal is also found in the South. Southern coke is only consumed locally, while that from the northern districts is distributed over the whole country.

The chief characteristic of the American coking industry is the fact that it is almost universally non-by-product coking. While Germany has been making giant strides in economical coke production by the introduction and improvement of plants for the recovery of the products of distillation, America is still content to employ the wasteful method of twenty years ago. This may be attributed in part to the very cheap price of coal which the American enjoys, and in part to the prevailing opinion that the product of the beehive oven is a better blast-furnace fuel than that of the by-product oven, and therefore more economical in the long run.

This opinion would, however, appear to be undergoing some change, judging by the number of by-product plants erected or being erected at the present time.

RECORD OF BY-PRODUCT COKE MAKING IN U.S.A.[1]

	Ovens		
Year.	Built.	Building.	Production (short tons).
1893	12	0	12,850
1896	160	120	83,038
1899	1,020	65	906,534
1902	1,663	1,346	1,403,588
1903	(a) 1,956	(b) 1,335	1,882,394

(a) Includes 565 Semet-Solvay, 1,335 Otto-Hoffman, and 56 Newton-Chambers.

(b) Includes 490 Semet-Solvay, 779 Otto-Hoffman, and 66 Wilcox.

It must be noticed that this development in the direction of by-product coking has taken place almost exclusively in conjunction with the erection of coking plants at the furnaces themselves, and is in no sense characteristic of the industry as a whole. Thus, not a single by-product oven has been erected in the Connelsville region in 1902, while, on the other hand, of all the firms which have recently erected coking plants at their own works, only one was employing beehive ovens.

The advantages of coking coal at the furnace where it is to be consumed, are that a better control can be maintained over its quality and that the coke undergoes a minimum of handling. On the other hand, for every ton of coke made, a ton and a half of coal must be hauled from the pit head, and although coal is carried more cheaply than coke, the difference in freight does not counterbalance the greater weight of raw fuel to be transported. The most economical plan is therefore to coke the coal at the mine and then transport it to the furnace.[2] Nevertheless, quite a number of firms are now

1. U.S. Geol. Survey, Mineral Resources, 1903.

2. An exception to this rule is found in the case of the Pittsburg furnaces situated on the river, to which coal can be carried from Connelsville by boat at 3 cents per ton compared with a railway-freight of 60 cents per ton on Connelsville coke to Pittsburg. Coke, of course, cannot be conveyed by water owing to its delicate character in handling.

day are supplied with coal. Their present scale of wages is as follows:—

Room-mining,	40 cents	per waggon	of 37 bushels.
Heading "	45 "	"	"
Wet-heading	47 "	"	"

The men find their own dynamite, and 5 cents a day are deducted from all wages to pay for the cleaning, trimming and locking of lamps.

Other labour in the mine is paid for on time-rates as follows:—

Haulers	\$2·10 and \$2·20 per day.
Trackmen	\$2·10 " \$2·20 "
Inside labourers ...	\$1·65 per day.
Rope riders	\$2·20 "
Trappers	\$1·00 "

The ovens, 650 in number, are of the usual beehive type, twelve feet high by seven to eight feet in diameter, and are built for the most part back to back in blocks of double rows about a quarter of a mile in length.

The coal is not touched by hand from the time it is placed on the waggon in the mine until it is drawn from the oven as coke. Dumped automatically from the waggon into pockets, the latter discharge it by gravity into cars standing below, and these are run by 25 h.p. electric larries along the top of the ovens. The movement of a lever "chutes" the contents of the car into the oven through a hole in the top of the latter. Each larry draws two cars of a capacity of 1—2 tons apiece, and three sets of larries and cars, each operated by a single man, with one helper to the three, charge 400 ovens as a day's work. The coke is drawn by hand through side doors on to the ground in front of the ovens.

After quenching and cooling, the coke is wheeled by barrows into railroad cars standing at a slightly lower level. No attempt is made to save or utilise any of the volatile products of the process, the latter burning freely as they emerge through a hole in the roof of the oven. By the system of replenishing adjacent ovens on alternate days, an empty oven is always flanked by two hot ones, which transmit sufficient heat through the walls to start the combustion of the fresh charge. When this point has been reached, the coking is continued at the expense of some of the raw material and no external source of heat is required.

The only labour employed during the process of coking is that required to level the charge in the oven as it gradually burns down, in order to ensure uniform coking. This work is paid for at the rate of 10½ cents per oven, and 20 ovens constitute an average day's work for a leveller.

Two qualities of coke are produced, depending upon the period of coking. One set of alternate ovens is charged on Mondays and Wednesdays with 111 bushels of coal, which coke for 48 hours, and on Fridays with 148 bushels which burn for 72 hours. The other set of alternate ovens receives the corresponding charges on Tuesdays, Thursdays and Saturdays. There is no charging or drawing on Sundays.

The yield is the same in both cases, namely, about 66 per cent. of the coal charged, but the slower coking produces a much larger coke, which is in greater demand for foundry work and commands a higher price than the smaller varieties. Eighty cents an oven is the price paid for hand-drawing, and a drawer will seldom average more than two ovens a day.

The number of men employed at Rainey with the 400 ovens at present in use is 420, the ratio of about one man to each oven being constant throughout the coking region.

The wages in force in 1903 in addition to those already quoted were:—

Firemen	$1·85 per day
Blacksmiths	2·40 ,,
Blacksmith's Helpers...	1·65 ,,
Ash Carters	1·50 ,,
Car Shifters	1·50 ,,
Yard Labourers ...	1·25 ,,
Stable Bosses... ...	51·50 per month
Stable Helpers ...	1·40 per day
Car Forkers	1·25 per car of 30 net tons (2,000 lbs.)
Watchmen	60·00 per month
Coke Forkers	25 cents per oven
Fire Bosses	2·75 per day
Lamp Cleaners ...	1·75 ,,
Yard Bosses	75·00 per month
Air Pumpers (inside)...	1·85 per day
,, (outside)...	1·60 ,,

A word must be said as to the personnel and efficiency of the labour. Made up from a variety of nationalities, the working population of a coke plant with its accompanying coal mines comprises less than 20 per cent. of native white Americans, and consists mainly of Hungarians, Italians, Poles, Slavs of various nationality, and American negroes. This heterogeneity has, from the employer's point of view, both advantages and disadvantages. The foreign element, not being permanent, learns little or no English, and hence, having no common language, it is practically impossible for the workers to combine successfully against the masters. As far as the coke-workers are concerned, no unions exist in the Connelsville region. This absence of a common tongue makes it of course more difficult to control and superintend the men, but a good deal of shouting seems as intelligible to them as any more definite commands. On the whole, the men are hard and efficient workers, and require but little overlooking.

The labouring population is continually changing.

The Europeans for the most part live in the humblest fashion, saving every cent they can, and when they have accumulated a few hundred dollars return to their homes veritable lords. Others remain a few months, take home their savings and return to work again when these have been spent. Many cross to Europe for the cold weather, notably the Italians, for whom an American winter is a severe trial.

This stream of labour from and to Europe is a very sensitive one, the slightest boom or depression being sufficient to set it in motion or to reverse its direction.

The shifting character of the labouring element is, however, less important than might at first sight be imagined. The work does not make very large demands on the skill of the workman, so that with a fair sprinkling of old hands among every fresh batch of immigrants, the work goes forward with little trouble.

Throughout the whole Connelsville region, the working population of each plant is housed at the plant by the operating company. This is necessitated by the fluctuating character of the labour, and by the fact that, as each new plant has been opened, the operator has had to create his own supply of men, the first step towards which was the provision of adequate housing accommodation.

The colony at the Revere works comprises, in addition to two hundred and forty dwellings, a general store owned by the company. It is thus self-contained.

The houses, constructed of wood in double blocks, are of three types. The best class of house, of which there are some forty or fifty, contains six rooms and earns a rental of $8 a month. These are all occupied by white Americans, and are separated territorially from the rest of the colony. The better class of foreigner lives in a five-roomed house, for which he pays $7½ per month. All rents include the free use of coal. Single men, of whom there are a considerable number, may either board with a

family, or live together, eight or nine in a small house, doing their own work. The standard of living is on the whole very low and very different from the average American standard. The Company, however, sells good and wholesome food, and the prices are not exorbitant, freedom to buy elsewhere maintaining competition. As a matter of fact the company's store is the universal provider and has done as much as $5,000 worth of business in a single month.

For the services of the medical man employed by the company there is a compulsory monthly charge of $1·00 for a family and 50 cents for a single man.

The one feature of the establishment open to criticism is the surface drainage of the settlement, which means practically an absence of drainage. This would probably be the source of considerably more trouble were it not that the colony is situated on the side of a fairly steep hill, which effects something, if not a great deal, in promoting sanitation.

Such a description would apply in essentials to any coking plant in the Connelsville field. The beehive oven is still, with the exception of a single plant employing the more economical system, universal in this region, and there would appear to be little disposition at present to displace it.

One of the reasons for the continued practice of this apparently wasteful method undoubtedly lies in the cheapness of the coal supplies. Nor is this cause likely to be soon removed, for the projected new Wabash railroad will open up fresh fields of coking coal which can be purchased for a fraction of the $1,000 an acre now asked for coal lands in the Connelsville field.

Another reason is that beehive coke is stated to be harder, and is certainly larger, than by-product coke, and commands a better price from blast-furnace and foundry managers than the latter variety.

Coke of the largest size, the product of the 72-hour heats, which is further carefully picked by hand, is consumed almost exclusively by foundries. It does not differ otherwise in chemical composition or in physical properties from the product of more rapid burning, and since the latest and most economical foundry practice is to crush the coke before charging into the cupola, the reason for this insistence on size is not clear. It is strong enough, however, to maintain the price at from 25—50 cents per ton in advance of the ordinary variety. The shorter heats produce a coke which, though somewhat smaller, meets all the requirements of the best blast-furnace practice.

Two slight economies have recently been introduced at one of the works near Uniontown, which have proved very successful and will probably be extended. One consists in the utilisation of the waste gases as fuel for producing the power to run the plant. Instead of burning at the top of the furnace and escaping in the usual way, the gases pass from the ovens into a wide flue, whence they are led to the boiler-house and there burnt to raise steam. During the year 1903 the gas from even a comparatively small number of ovens had sufficed to run a 1,000 h.p. plant, and a saving of $8,000 was effected. The coke showed no deterioration in quality, and flues are now being constructed in a larger number of ovens with the object of obtaining the whole of the motive power from waste gases. This is a simple and effective economy as far as it goes, though but little of the waste products can be utilised in this way.

The second economy lies in the direction of substituting machinery for hand-labour in the drawing of the ovens. Although not in any general use as yet, the electrical coke-drawing machine has already passed the experimental stage, and is giving satisfactory results at the Continental Works No. 3, where it has been evolved. The machine runs along the front side of the ovens, scrapes the coke out

on to a kind of apron in front of the door, and, by means of moving tables, transfers the coke to the cars standing below without any handling and with a minimum of breakage.[1] One man, operating the machine, can draw twenty-two ovens in five hours, while a second man follows to clean up the ash which is drawn on to the ground, and to build up the oven doors ready for the next charge.

The first experimental machine was said to have reduced the cost of drawing to 40 per cent. of the old figure, quite apart from the economy arising from the lessened handling of the coke; and with the improved type now under construction, still greater saving may be looked for.

Assuming 140 bushels as an average charge, and a 66·6 per cent. yield of coke, the cost of hand-drawing per ton of coke is 22½ cents. Add to this 5 cents per ton for placing in the cars, and the labour cost of transference of a ton of coke from oven to car is 27½ cents.

With the advent of a successful drawing-machine, the labour cost per ton of coke is only 2½ cents, allowing $2 as a five hours wage for drawing 22 ovens with the machine.

In machine-drawing the coke is transferred without further cost to the cars, although this allows for no hand-picking. Including cost of power, depreciation of machine and interest on its cost, and a liberal estimate for hand-picking, the coke might be drawn and loaded on cars for less than 12 cents a ton.

The total cost of producing a ton of best Connelsville coke in March, 1904, was stated by the manager of a coke works to be $1·17—$1·20 on cars at the ovens. The selling price at the same period was $1·50.

The average prices of Connelsville coke and of Durham coke during the last few years have been approximately in the proportion of one to two.

1. A description of this machine has appeared in the Iron and Coa Trades Review, 1904.

This difference is largely attributable to the cheaper raw material which the American enjoys. The average prices per English ton at the pit's mouth here and in the United States for the last twelve years of the nineteenth century were:—[1]

	United Kingdom.		United States.	
	s.	d.	s.	d.
1889	6	4¼	5	3½
1890	8	3	5	2¾
1891	8	0	5	3½
1892	7	3	5	4¾
1893	6	9½	5	4
1894	6	7½	5	1
1895	6	0½	4	9¼
1896	5	10	4	9¼
1897	5	11	4	7½
1898	6	4	4	5
1899	7	7	4	8½
1900	10	9¾	5	3¾

The opinion has been expressed that this advantage in favour of the American with respect to raw material is due, partly to the greater depth at which British coal lies and partly to the greater use of coal-cutting machinery and electric traction in American mines.[2] If true, this largely accounts for the fact that during the last few years the wages paid in the Connelsville region have been about double those earned in Durham, although the price of Connelsville coke has been only half of that of the English commodity.

It has been stated, in effect, that the United States Steel Corporation possesses in the person of the Frick Coke Co., a practical monopoly of the Connelsville coke industry,

1. Brassey and Chapman's "Work and Wages," 1904, p. 44.
2. Brassey and Chapman's "Work and Wages," 1904, p. 36, *seq.*

and can almost fix its own price.[1] This statement was controverted by the manager of an independent concern in this same field, who stated that if the Frick Coke Co. bought up to-day every coke plant in the region and attempted to control prices, outsiders could go in and undersell them to-morrow. The only condition for the monopolisation of the coke industry would be the purchase of every acre of coal land in the country. Much of this is at present not only not developed, but not even explored. It is significant that a large number of the works which have arisen during the last few years on the newly-developed field to the south-west of Connelsville, are owned by independent operators.

Iron Ores. One of the greatest and at the same time most indispensable assets of the iron industry in America is the great wealth of rich ores which that country possesses within its own confines. It holds a unique position among the large iron-producing nations in being independent of foreign supplies for its chief raw material. The production of iron-ore in 1903 reached a total of 35,019,308 gross tons; the imports for the same year were 980,440 tons.

Moreover, American ores surpass in richness those of most European countries. The ores of the Lake Superior region, from which it is estimated that 75 per cent. of the total pig-iron production is at present derived, contain on the average from 56—65 per cent. of metallic iron.

Of the total production in 1903, 86·6 per cent. consisted of red hematite, derived mainly from Minnesota, Michigan and Alabama; 8·8 per cent. of brown hematite, mined almost entirely in the Southern States; 4·5 per cent. of magnetite, chiefly from New Jersey, New York and Pennsylvania; and 0·1 per cent. of carbonate ores, derived exclusively from Ohio and Maryland.

1. Report of the British Iron Trade Association, 1902.

The first point of interest is the predominating influence of what is termed the Lake Superior region. This embraces the Mesabi and Vermilion ranges in Minnesota, the Marquette range in Michigan, and the Menonimee and Gogebic ranges which lie in both of the two last-named States.

Strictly speaking, the Michipicoten range, in Canada, which was opened in 1900, should be included in the same category, since the greater portion of its ore is used in the United States.

It is only during recent years that this busy region has sprung up into its present important position. The Vermilion range was first exploited in 1884, and the Mesabi range, which now exceeds in production the four others combined, has only been worked for 15 years.

Commenting, in 1902, on recent changes in the location of the blast-furnace plants of the country, the *Cleveland Iron Trade Review* remarked "that the districts using Lake Superior ores are increasing their relative importance in a most marked manner, and the districts using local ores are either only holding their own as to actual tonnage or are declining."

The ores mined in the Superior region are almost exclusively red hematites, containing a high percentage of iron. Their uniformly high quality is illustrated by the following analyses taken from the U.S. Geological Survey:

GOGEBIC RANGE.

Ore.	Iron.	Phosphorus.	Silica.	Sulphur.	Moisture.
Ashland	60·39	0·038	6·53	0·012	—
	53·99	0·035	5·83	0·010	10·59
Cary	60·07	·078	6·95	·006	—
	54·31	·070	6·28	·005	9.57
Norrie	63·11	·037	4·15	—	—
	56·25	·033	3·70	--	10·86

MARQUETTE RANGE.

Ore.	Iron.	Phosphorus.	Silica.	Sulphur.	Moisture.
Angeline	66·81	·011	—	—	—
(hard)	63·33	·010	—	—	5·21
Richmond	44·00	·036	33·45	·006	—
	43·15	·055	32·81	·006	1·91
Lillie	59·45	·070	6·16	·013	—
	52·01	·061	5·39	·011	11·52

MENOMINEE.

Ore.	Iron.	Phosphorus.	Silica.	Sulphur.	Moisture.
Barton	58·44	·461	4·79	—	—
	54·56	·430	4·47	—	6·64
Hiawatha	56·00	·252	7·28	·019	—
	52·09	·234	6·77	·017	6·97
Lerida	59·03	·082	6·96	—	—
	54·73	·076	6·46	—	7·28
		MESABI.			
Admiral	63·80	·027	4·90	·006	—
	58·82	·025	4·52	·005	7·80
Elba	61·67	·033	3·76	·008	—
	56·29	·033	3·98	·007	8·72
Kanawha	53·69	·082	—	—	—
	46·97	·072	—	—	12·51
Penobscot	59·88	·054	6·66	—	—
	54·39	·049	6·05	—	9·16
Skilling	62·18	·063	3·81	·010	—
	56·00	·056	3·43	·009	9·93
Wallace	62·95	·051	3·67	·006	—
	57·55	·046	3·35	·005	8·57
		VERMILION.			
Chandler	63·92	·044	4·73	—	—
	60·65	·042	4·49	—	5·12
Sibley	65·03	·032	3·45	—	—
	61·59	·030	3·26	—	5·29
		MICHIPICOTEN.			
Helen	57·65	0·094	7·40	0·177	—
	54·06	0·088	6·94	0·166	6·22

For purposes of sale, the ore is graded by composition and by structure. The desirable elements in an iron ore are high percentage of iron, low percentage of phosphorus and low percentage of moisture, which latter only adds to the cost of transportation. Accordingly, a base price is fixed for a theoretical ore containing certain definite proportions of these three constituents, and as any particular ore rises above or falls below the theoretical percentage with respect to each of these constituents, the base price is raised or lowered according to a sliding scale.

All ores are classed in the first instance, according as they contain less or more than 0·045 per cent. of phosphorus, into Bessemer and non-Bessemer ores. The former naturally command the higher prices; indeed, it is only the recent development of the basic open-hearth process

that has caused the non-Bessemer ores to have any considerable sale at all.

The ores are further divided into those from the Mesabi mines, on the one hand, and those from the other four ranges, known comprehensively as "old-range" ores, on the other. Mesabi ores are all dust-fine, and present considerable difficulties in smelting, giving rise to slipping and explosions in the blast-furnace. They are best treated by mixing with a fair proportion of the harder and more lumpy old-range ores, the smelting of Mesabi ore exclusively being quite exceptional. This difference in structure between the two varieties produces a difference in selling price in favour of "old-range" ores.

The base prices for the various varieties of ores were, in 1903:—

Quality.	Iron.	Analysis. Phosphorus.	Moisture.	Price of base ore.
Mesabi Bessemer	63 %	0·045 %	10 %	\$4·00
Mesabi non-Bessemer	60 %	above 0·045 %	12 %	\$3·20
Old Range Bessemer	60 %	0·045 %	10 %	\$4·50
Old Range non-Bessemer	60 %	above 0·045 %	12 %	\$3·60

These prices include shipment down the Lakes and are for ores f.o.b. at lower Lake ports.

Ores which differ in composition from the base command higher or lower prices according as they contain more iron and less moisture, or less iron and more moisture, fixed differentials existing for each unit of change in respect of each constituent.

But, further than this, the Mesabi non-Bessemer ores are classified under three heads according to hardness. The price of a first-class ore analysing: iron 58 per cent., moisture 10 per cent., was in 1903 \$3·16. The differential between first and second-class ores was 15 cents per ton, and between second and third-class 10 cents per ton, always in favour of the harder ore.

Less than 35 per cent. of the Lake ores mined now come into the open market, the remainder being used directly

by the companies which mine them. In 1902 the shipments from the Steel Corporation's Lake Superior mines alone amounted to 16,174,473 tons, or 58·6 per cent. of the whole, and several large independent firms of steel manufacturers, including Jones and Laughlin's, of Pittsburg, and the Lackawanna Steel Co., of Buffalo, were mining their own ores.

But even where ores have been sold in the open market competition has been fettered by the existence of a pool known as the Bessemer Ore Association. In the first year of its existence (1896), this pool advanced the base price of Bessemer old-range ores by more than $1·00, and although it did not include all the mines, apparently the leading mining companies belonged to it, and its control over prices has been usually quite effective. At the same time, although the pool adopted the policy of alloting output, the increase in production has been rapid, and it cannot be said that the output has been restricted.

The year 1904 saw an end, for the time being at any rate, of the combination of Lake ore interests. The slackness of furnace operations and the accumulation of large stocks of ore at the docks meant a serious curtailment in prospective ore production and shipping for the coming year, and it would appear that dissatisfaction with the allotments and inability to agree upon prices were the chief causes of the non-renewal of the Ore Association. Both cause and effect of this non-renewal are to be seen in the following statement:—"Some sales of standard Mesabi ore, guaranteed 63 per cent. iron and 0·04 per cent. phosphorus, have been made this week (May 21st, 1904) for $2·85 Cleveland delivery. This price is 40 cents below the rate tentatively agreed upon at a recent conference of ore interests, and $1·25 below the price of the same ore last year." [1]

1. Iron Age, May 21st, 1904.

The Assemblage of Materials. The predominance of the situation of the raw materials as a factor in determining the geography of the industry has already been dwelt upon. It is now necessary to consider the wonderful organisation whereby these raw materials are assembled at the furnaces in each of the three principal smelting districts described on pp. 29 and 30.

The conditions of transportation in the South call for little remark. That district is exceptionally fortunately situated with respect to its supplies of ore and fuel and the cost of assemblage is lower there than in any other district. In some cases both ore and coal lie within sight of the furnaces.

Writing in 1876, Sir Lowthian Bell estimated that the carriage for bringing the materials together for smelting a ton of pig-iron in Alabama from native ore and native coal was:—

	s.	d.
Coal...	3	0
Iron Ore...	5	0
Limestone	1	6
Total	9	6

Since that time great developments have taken place in railroad transportation. Average freight rates dropped nearly 50 per cent. between 1870 and 1880, and in some cases again nearly 50 per cent. between 1880 and 1890;[1] and although, no doubt, railway economy during the last decade has been mainly concerned with long-distance transportation, a general saving has been effected all round by the introduction of the larger car and of mechanical devices for loading and discharging freight.

In the Pittsburg district and Western Pennsylvania and

1. See special Volume of Iron and Steel Institute Journal, 1890, pp. 48, 49; also American Industrial Conditions and Competition, 1902, p. 99.

Ohio, the conditions with respect to raw materials are entirely reversed. While the fuel lies at Connelsville conveniently situated for most of the furnaces, the whole of the ore smelted in this district has to be hauled an average distance of 1,000 miles from the head of the great Lakes. The organisation of the transportation of these ores is perhaps the greatest factor in the economical production of iron and steel in the United States; for in spite of the adverse geographical conditions by which it is surrounded, this district is by far the largest and the most progressive of the three principal iron and steel producing centres in that country.

The ore which is mined in one of the five large ranges lying in Minnesota, Wisconsin and Michigan, is conveyed by rail to the nearest Lake port, a distance varying from 12—100 miles. Transhipped to boats specially designed for ore carrying, the ore is then conveyed by water to the lower ports on Lake Erie, an average distance of 750 miles. Then a third trans-shipment takes place, and the ore is distributed by rail to the various smelting centres of Ohio, Pennsylvania and West Virginia. In the case of those furnaces which are situated on the Lake front, as at Buffalo, Cleveland and Lorain, this last transhipment is made directly into the furnace yards, so that not only rail-freight, but also cost of handling from car to yard at destination are saved.

The ore is loaded at the mines direct into 50-ton steel cars, which are hauled in long trains to the various ports of shipment. The cars for the most part must return empty, earning of course no profits, and the double distance must therefore be included in estimating the cost of ore-transportation.

The upper Lake ports possess a very perfect equipment in respect of docks and facilities for loading the ore boats.

These docks vary in capacity from 30,000 to 60,000 tons

of ore each, and consist of timber-work pockets for holding the ore and delivering it by gravity into the vessels. The ore-carrying trains run on tracks laid above the pockets, into which they deliver their charges by the opening of the bottom of the car. Practically the whole of the double transhipment from train to boat is thus effected by gravity.

The ore-carrying ships are specially designed for the purpose they have to fulfil, being generally of such a type as to afford the greatest possible net space for ore. To this end all the necessary propelling machinery is concentrated as far as possible in one portion of the boat, and the remainder consists simply of one large room, divided in some cases into sections, and reached through hatches which extend the whole length of the ore compartment.

With the recent rapid development of ore-handling machinery, it has become necessary to modify the design of the ships so as to allow the maximum percentage of a boat load of ore to be removed by these machines at one step. It is always cheaper to unload the last few tons of ore from the corners and angles of the compartment by the help of hand-labour, but by increasing the size of the hatchways and diminishing the distance between them, the percentage of a load which can be economically removed by machinery has been increased up to 98.

Some few years ago a type of boat known as the whale-back, built very low in the water, without bulwarks and with rounded deck and ends much resembling a torpedo boat, had a considerable vogue. But this type is now obsolete, the ordinary shape of ship being regarded as more seaworthy and offering less resistance to the water.

The whale-backs possessed a carrying capacity of some 3,000—5,000 tons, and in the later boats these figures have been materially increased. On April 19th, 1904, there

was launched at Lorain, Ohio, the largest vessel yet built for service on the great Lakes, and, indeed, the largest freight vessel in the world.

The "Augustus B. Wolvin," built by the American Shipbuilding Company, is 560 ft. in length, 56 ft. wide and 31 ft. deep, and will carry from 10,000—11,000 tons of ore and 300 tons of fuel on an 18 ft. draught. This carrying capacity is equivalent to 333 car-loads or 11 train-loads of ore. The ore compartment consists of a single chamber, in width equal to that of the boat, and extending about four-fifths of the total ship's length. In section it is of an arched type, built without stanchions and with wide angles between floor and sides, with a view to as complete and rapid machine-unloading as possible.

The load is taken aboard through 33 hatches, each 11 ft. wide, running from side to side of the boat, and it is anticipated that by means of the most modern unloaders this immense cargo can be discharged in six hours.

A boat of such size and design should represent a very high degree of economy in water transportation, and if expectations are fulfilled, a general increase in the size of the transporting unit may result.

The journey from Lake Superior to lower Lake ports occupies from four days upwards, and the round trip, including loading and unloading at each end, a couple of weeks. Coal and general merchandise are carried on the return trip, or else the ships go up in ballast. There is not sufficient trade up the Lakes to equal the ore-carrying capacity in the downward direction, and rates are consequently lower in the former case, being 34 cents per ton for coal for the whole journey.

The distances of Lake Erie ports from those on Lake Superior, and their relative importance as exhibited by tonnage of ore received, are:—

To	Total Tonnage received at Lake Erie port in 1903 (long tons)	From Duluth and Superior (Miles)	Two Harbours (Miles)	Ashland (Miles)	Marquette (Miles)	Escanaba (Miles)
Buffalo and Tonawanda	2,149,901	985	961	939	749	699
Erie	1,257,798	917	893	871	681	631
Conneaut	3,903,937	889	865	843	653	603
Ashtabula	4,242,160	876	852	830	640	590
Fairport	1,434,342	851	827	805	615	565
Cleveland	4,434,160	834	810	788	598	548
Lorain	990,490	814	790	768	578	528
Huron	486,106	805	781	759	569	519
Sandusky	130,532	800	776	754	564	514
Toledo	652,305	784	760	728	548	498

There were also shipped in 1903 to Chicago and Milwaukee, on Lake Michigan, the following quantities of ore:—

Chicago	3,967,819	809	785	763	573	277
Milwaukee		743	719	697	507	192

Unloading Ore at the Docks. The designing and manufacture of machinery for rapidly and cheaply unloading ore from boat and transferring it to car has been mainly in the hands of two firms—the Brown Hoisting Company and the Wellman-Seaver-Morgan Company, both of Cleveland, Ohio.

Until about fifteen years ago the method of unloading ore from boats was to shovel it by hand into buckets depending from the rigging, which were raised or lowered into the hold by windlass or steam power. The contents were dumped into hand-barrows on deck and wheeled off to be deposited on the dock.

The first improvement was the employment of standard bridges supported by steel A-frame piers and mounted on rails, from which the buckets were raised and lowered.

Such bridge cranes are usually provided with movable extensions or "aprons," which can be lowered right over the hatchway when the boat is in position, and afterwards

raised flush with the dock wall so as to clear the latter of obstruction in ordinary times. The bridges move along rails on the dock and can thus be stationed at suitable intervals to accommodate boats with hatchways of varying sizes. The hauling instrument was still the bucket, filled by hand, and dumped into railroad cars or on to the dock itself. In the latter case, ultimate transference to cars was made by steam-shovel. The total cost by this method of working was 18 cents per ton from boat to car, of which 14 cents was consumed in actual labour.

The last-named item was first materially reduced when, six years ago, Hulett introduced the principle of an appliance which should dip into the hatchway and fill itself automatically with ore. Such appliances are of various tyes, the two most important being the clam-shell and the grab-bucket.

Clam-shells of 1½ tons were adapted to the Brown bridges on the C. and P. Docks at Cleveland in 1901, and the cost of unloading was thereby reduced to 7 cents per ton. Twelve short Brown bridges fitted with 1½ clam-shell buckets unloaded 6,000 tons of ore in 12 hours.

Such an arrangement, however, was only a makeshift, the bridges not having been designed for use with clam-shells.

A quite special type of unloading-machine is the Hoover and Mason machine, erected on the Cleveland Docks. Two-and-a-half-ton clam-shell buckets attached to short inclined bridges with "aprons" transfer the ore first into large bins—which form the hind portion of the machine,—and, finally, to the railroad cars standing below. The feature of this machine is that, while loaded cars are being withdrawn and their places under the unloader taken by empties, the bins act as a reservoir for the ore, and unloading from the boat is uninterrupted. These bins have a capacity of 4,000 tons—almost a boatload—and they are invaluable at a time of a shortage of cars. It

should be pointed out here that the ore-carrying season on the Lakes lasts only from about May to November, with the result that during these seven months, traffic is being carried on at very high pressure, and no time is to be lost. Hence the very great importance which is attached to rate of unloading, rather than to outlay on machines, since time enters as such a large element into cost.

The Hoover and Mason machine can unload 6,000 tons in from 8—10 hours, and this at much less than 7 cents per ton, but the proportion of a boat-load which it can economically remove is as low as 60 per cent., so that total cost of unloading, when the last 40 per cent. is emptied by the bucket method, is considerably enhanced. A further advantage possessed by this machine is that the employment of bins allows the cars to be loaded and very carefully weighed in a single operation.

One of the finest plants until about three years ago was that erected by the Wellman-Seaver-Morgan Company for the United States Steel Corporation on the docks belonging to the latter company at Conneaut Harbour on Lake Erie. This consists of four machines, side by side, each provided with a 10-ton grab-bucket on a fixed arm, which is raised by a see-saw motion of the rig which supports it. This rig has a lateral motion, so that when it has raised the arm it runs back and can deposit the contents of the bucket in the cars on the dock.

The bucket has a 14 ft. reach, and the arm supporting it a rotary motion, so that every corner of the boat can be reached. Ninety-five per cent. of a boat-load can be economically removed without any handling. The bucket deposits its contents into 10-ton intermediate cars, which either carry it along the ore bridge and dump it on to the back of the dock, or else are drawn away and emptied into railroad cars. The intermediate cars not only save travelling on the part of the bucket, but obviate any delay in the removal of railroad cars. The total crew on the

whole plant is seventeen men—one general superintendent, four men in the hold and three men on each machine—one down by the bucket-arm, one controlling the steam and one the cars.

The record for the plant is 5,000 gross tons in 3 hours 56 minutes. During about six months of 1903, the plant negotiated 2½ million tons of ore. With the new type of boat already described, it is estimated that this plant will remove 10,000 tons in six hours. With such speeds it will readily be believed that, although the cost of the whole plant was $250,000, the cost of unloading, including interest and depreciation,[1] is less than 4 cents per ton, about half of which is for labour. The driving power is hydraulic.

Quite the latest development in fast-plant construction is represented in the four machines built in 1904 by the Brown Hoisting Company, also at Conneaut.

The 7½-ton grab-buckets depend by rope from a travelling trolley which runs back and forth on the bridge above, and along the apron, in which the bridge ends, over the hatchway.

The operator occupies a point of vantage on the trolley, whence he can see down into the boat and thus adjust the position of the bucket to a nicety. He controls the whole of the machine, including its lateral motion up and down the dock from hatchway to hatchway; and he and an oilman constitute the operating crew. The ore is dumped either on the ground behind, or through funnels into railroad cars. These funnels can move up and down over three sets of rails, and thus additional car accommodation is provided.

The bucket makes the round trip from hatchway to car and back to hatchway in one minute. The whole of the machinery is worked electrically, propulsion being on the

1. 6% allowed for interest, 10% for depreciation, and ½—1% for repairs.

third-rail system. One-hundred-and-fifty horse-power is available for vertical, and 100 h.p. for horizontal motion of the bucket. The plant will unload 98 per cent. of a cargo, but the last few per cent. are moved more economically by hand. The operating cost is said to be 2 cents per ton of ore. Like the Hulett patent, this one consists of four rigs of bridges, and is operated by six men—two men on each trolley and two oilers.

Reference has already been made, in speaking of the Bessemer Ore Association, to the prices of iron-ore, and it will be remembered that these prices were for ore f.o.b. at lower Lake ports. These prices, therefore, include freight costs down the Lakes. Freight rates from Duluth to Lake Erie ports are fixed just before the opening of the carrying season in each year, and in determining the rate, operators are mainly influenced by their estimate of what the coming season's transportation will amount to. This results from the presence of "tramps" in the business, which in a dull season go in and bring down odd lots of ore for less than the contract price.

In 1903 the contract rate was 85 cents a ton (of which 21 cents was for unloading), and the "wild rate" (*i.e.*, the rate charged by tramps) 80 cents a ton.

In the previous year, which was a very busy one, the wild rate rose to $1·25.

The contract rate for 1904 was 70 cents (17 cents being for unloading).

Thus the cost of ore, in so far as the element of freight is concerned, is not a monopoly price, but is subject to fairly effective competition.

CHAPTER IV.

Pig-Iron Production.

Pig-iron production in the United States is referred broadly to those districts mentioned in Chapter II., the conditions in which, with respect to raw materials and their transportation, have been discussed. A rather more detailed classification is that which assigns this branch of the industry to five centres of production, instead of three, as follows:—

(1) The Central West (Western Pennsylvania and Ohio).
(2) The North-West (Illinois, Michigan, Wisconsin, and Minnesota).
(3) The New England States and the Seaboard States (New York, New Jersey, Eastern Pa., and Maryland).
(4) The Southern States.
(5) West of the Mississippi.

The relative importance of these, as exhibited by their outputs of pig-iron in 1903, was:—

	Long Tons.	Percentage.
Central West	9,568,248	53·1%
Seaboard and New England	3,037,606	16·9%
Southern States	2,900,856	16·1%
North-West	2,220,600	12·3%
West of Mississippi	281,942	1·6%
	18,009,252	100·0%

Conditions in the North-West are identical with those in the Central West, viz., dependence upon Lake ores and Connelsville coke; and these districts constitute the eastern and western limits of that zone spoken of on p. 30.

Production west of the Mississippi is confined practically to two localities, and, indeed, to two works in Colorado and California respectively, each of which is favourably situated in respect to local supplies of ore and fuel. Statistics show the increasing dependence of the American industry upon Lake ores and the consequent tendency to concentrate production in the Central West and North-West districts. It was estimated that in 1903, 70—75 per cent. of the pig iron made was smelted from Lake ores. The only hope for the Eastern furnaces, with the exception of such as the Wharton and Port Henry plants—which enjoy quite special facilities and do not strictly fall into the category of the East—would seem to be in the establishment of their own coking plants, the employment of by-product ovens, the utilisation of waste-products such as slag, and especially the employment of the waste gases in the production of power by means of gas-engines.

Of these five districts, the Central West is seen to be by far the largest producer, and this supremacy extends also to the actual practice of iron-smelting. A variety of considerations, in part natural, in part the result of accident, have combined to make Pittsburg probably the greatest iron-producing centre in the world. The natural conditions upon which the industry is dependent have been already partly described. It remains to give an account of actual metallurgical operations; and this will best be accomplished by descriptions of works visited which, if no one of them can be said to be typical, will be so selected in variety and number as to accurately picture what it is desired to bring out.

The Eliza blast-furnaces of Messrs. Jones and Laughlin, Pittsburg.

This plant consisted, at the time of the writer's visit on March 1st, 1904, of five blast-furnaces, one of which had just been completed and was not then blown in on account of an impending coal strike, which, however, never took place.

The four older furnaces were each 100 ft. in height with 16 ft. hearths, and fitted with from 16—20 tuyeres. Arrangements for cooling the boshes consisted of bronze cooling-boxes placed inside cast-iron boxes which were let into the walls at different levels above the tuyeres. This is the general practice in the West, although, as will be seen later, opinions differ as to the relative advantages of cooling-boxes and cooling-plates.

The thickness of the walls at the boshes was 31 in. Exclusively Mesabi ore, and that mostly dust-fine, was being employed for the production of a Bessemer iron. The composition aimed at was: silicon 0·75—1·10 per cent., and sulphur below 0·040 per cent. To produce such an iron, the temperature was not allowed to rise above 800°, and the blast-pressure averaged 15 lbs. per square inch, although, as is the case in most American works, more attention was paid to maintaining a constant volume of air per minute than a constant blast-pressure. The coke consumption—1,900 lbs. per net ton (2,000 lbs.) of iron produced—was considered rather high for this district. The ore consumption was 3,800 lbs. per ton, and iron and the cinder produced, 850 lbs. This low figure means the removal of little heat through the cinder, and consequently a hot product of metal. Tapping took place every four hours, and each furnace was making an average of 500—520 tons per 24 hours. The record at this particular works was stated to be, from a single furnace 670 tons in 24 hours and 4,500 tons in a week. A feature in which the American furnaces differ from those in this country is the

neatly-kept whitewashed cast-house by which the furnace front is enclosed. Except in case of emergencies, sand casting beds are in many works quite obsolete, the iron being transferred directly in 25-ton ladles from blast-furnaces to metal-mixer, or else manipulated by the Uehling, Davis, or other form of pig-casting machine.

At the Eliza furnaces, three of these machines are in operation for the handling of the metal on a Sunday when the steel works are closed. The cost of operating is 3 cents per ton of pigs cast.

The life of a furnace making 600 tons per 24 hours is about six or seven years, a lining being generally available for about 1,000,000 tons of metal. This figure had already been exceeded by one of the Eliza furnaces which was just on the point of being put out of commission.

The chief drawback to the use of the otherwise extremely valuable Mesabi ores is their fine state of division, which very readily leads to unequal distribution and reduction in the furnace, and consequent slipping and explosion. Apart from the loss of material which such explosions occasion, the pouring out of large volumes of fine iron-ore dust from the top of the furnace may become a nuisance and cause public inconvenience in a populous neighbourhood. At the time of the writer's visit an injunction had been obtained against the firm of Jones and Laughlin, restraining them from the use of dust-fine ores.

Trouble of this kind has led to a reconsideration of the question of blast-furnace construction. It is now recognised that the rich Superior ores, and particularly the fine Mesabi variety, for which most of the 100 and 110 ft. blast-furnaces were built, will give rise to less slipping and all the evil consequences which slipping entails if treated in smaller furnaces and with a shorter burden. And, although the last word in blast-furnace construction has no doubt yet to be said, the consensus of opinion is at present in favour of a blast-furnace with a

maximum height of 80 or 85 ft., for the treatment of fine ores. The place of the higher furnaces is more and more seen to be in the smelting of poor and refractory material, which requires a greater amount of reduction and a longer exposure to the action of the reducing gases. This change in view is typified in the construction of the fifth furnace of the Eliza plant, which is 85 ft. high, and fitted with twelve tuyeres only. As illustrating the despatch with which constructional work is accomplished in America, it may be mentioned that the time spent in erecting this furnace, including the demolition of an old coking plant which stood on the same site, occupied only eight months. The new furnace is provided with three Allis-Chalmers blowing-engine (each capable of blowing 21,000 cubic feet per minute), two of which will be in regular operation, the third being a stand-by in case of breakdown. The policy of sinking some £10,000 for an emergency engine was justified in the remark of the manager that it would prevent a loss of production, in case of an accident, of some 250 tons of iron per day, and thus pay for itself in from two to three weeks. This attention to proper proportion between power and plant and the willingness to provide against possible stoppage is one of the characteristics of American blast-furnace practice.

All the furnaces on this plant are fitted with gun tapping-hole machines, and a compressed-air drill is employed to penetrate the greater part of the fire-clay when the furnace is to be tapped. The labour consists of five men on each furnace front, together with one waterman between two furnaces, and a boy sampler for the lot.

One of the most important points about an American blast-furnace plant is the arrangement which has to be made for the handling and storing of large stocks of raw materials, especially ores.

It has been pointed out that traffic on the Lakes is

confined to seven months in the year, from May to November, and that, consequently, provision must be made for a large supply of ore to last over the winter months. The storing of this necessary surplus is in part undertaken by the ore-carriers, on the docks at the lower Lake ports; but largely also by the smelters themselves at their own furnace yards.

At Jones and Laughlin's works the cars which bring the ore from Lake ports are run on to trestles in the furnace yard, and then dump their contents by bottom-dropping through the trestle girders on to the yard below, where the ore remains during the winter.

As required from time to time, the ore is removed by means of 50- and 100-ton railroad cars, filled by steam-shovel, to a series of bins, which contain also the fuel and limestone.

The raw materials are transferred next by gravity into electric trolleys, of which two go to each furnace, and each of which is operated by two men; these deposit their contents in the skip-hoist, ready to go to the furnace top. The two skips, which discharge automatically, and the two bells with which the furnace is built, are all under the control of a single operator placed at the foot of the furnace.

In addition to the blast-furnace plant, Jones and Laughlin own large steel works on the opposite side of the Alleghany River from the Eliza furnaces, and are one of the largest private firms engaged in the manufacture of iron and steel in the United States. It is of interest to examine the position of such a firm, and to see in what way it can hold its own in competition with the Steel Corporation, and working, so to speak, under the very walls of that gigantic trust.

It almost goes without saying, considering the influence the trust exerts in the so-called open market, that the firm of which we are speaking is a large holder in coal and ore

properties. It possesses, in fact, its own ore-quarries at Mesabi, and a fleet of boats for transport on the Lakes. In view of the advantage which the Steel Corporation holds over it in the matter of railroad haulage, it has at present in hand the construction of a private railway from one of the lower Lake ports to their furnaces in Pittsburg.

This will, no doubt, materially reduce the third item in the following analysis of standard rates for delivering ore at furnace in Pittsburg, under which rates independent firms might be presumed to operate:—

Cost of quarrying Mesabi Ore ...	40 cents.
Lake Freight	80 ,,
Railway freight to Pittsburg... ...	\$1·10 ,,
	\$2·30 cents.

In the matter of fuel, again, this firm is very favourably situated.

The coal from its own mines at Connelsville is hauled by boat down the river and coked at the furnaces. This is effected at a cost of 3 cents per ton of coal, or about 6 cents for sufficient coal to yield a ton of coke, compared with 60 cents railroad freight paid by the Steel Corporation on coke from Connelsville.

With such a ridiculously low freightage for coal as 3 cents per ton, it is not to be wondered that economy was not being attempted in the direction of by-product recovery. Open-top beehive ovens, accordingly, were being employed for coking.

But the opinion was also expressed, and it is typical of the all but universal feeling in America, that although beehive coke is apparently more costly than by-product coke, yet the former is, in some indescribable way, better, and will stand heavier burdens, and works more economically in the furnace, than the by-product variety. The

secret of the whole matter probably lies in the extreme relative cheapness of even the best coke in the Pittsburg district.

It will have been gathered from the foregoing description that this works is thoroughly up to date in the matter both of construction and of equipment. It may be here pointed out that except for about 10 cents per ton of mining royalty on the ore, the total cost of producing pig-iron—some $10 to $16 a ton—is a labour cost, and that therefore the greater the amount of labour which can be dispensed with by the use of machinery, the lower the cost of production of pig-iron. The experience of the Carnegie Steel Co. has been that $1,000 is profitably spent on such machinery as will replace the labour of one man.

The labour charges for actual operating at this works were stated to be 40 cents per ton of iron; for repairs 12 cents per ton; and total charges of labour, repairs, interest on investment and depreciation, about $1·00 per ton. This figure will not differ greatly at any of the works in the Pittsburg district where the same state of efficiency holds in respect to equipment with labour-saving machinery.

The blast-furnace plant of the Cambria Steel Company, Johnstown, Pa.

Another blast-furnace plant which merits some special description is that attached to the large Cambria steel works at Johnstown, Pa., which, together with the Pennsylvania steel works at Harrisburg and the Maryland Steel Company's works at Sparrows Point, Md., is said to be controlled by the Pennsylvania Railroad Company. The Cambria steel works comprise several plants in different parts of the town, of which the blast-furnaces form one section.

The blast-furnace plant possesses a splendid equipment for the economical handling and storing of ore.

As the cars of ore come into the yard they are run one

by one on to a car-dumper—a huge piece of machinery which tightly grips the car and then turns it over bodily so as to discharge its contents into the company's private cars standing on an adjacent siding.

The initial cost of a car-dumper is large, but when it is considered that some 700 cars are arriving daily, and that the storage charge on these is 2–3 cents each per day, the policy of such an investment needs no demonstration.

The next step in the handling of the materials is their removal to bins, whence they are transferred by electric traction to the skips on the furnaces.

On the floors below the bins run a number of electrically propelled cars into which the ore falls by gravity and on which it can be weighed by one of the two men who run each car.

Each furnace can be kept supplied by two such cars, and including the operator of the skip and double bell, a 300-ton furnace is kept fully charged by five men on each twelve-hour turn. As soon as more bins can be erected, the same result will be effected for the more recently-erected 600-ton furnaces. Behind the bins are large stock-yards, spanned by two bridge cranes with depending grab-buckets to charge the bins during the close season of Lake shipping.

The provision for economic handling of materials was, at the time of the writer's visit, still far from complete, but had given excellent results so far. It was stated that a single man could, within five minutes, transfer the contents of a large car into the bins.

Another interesting feature of the Cambria plant was the neat method of handling the slag in use at one of the furnaces.

Roughly speaking, with every ton of iron, from a half to one ton of slag is produced. To a plant turning out 20,000 to 30,000 tons of iron a week, the disposal of an almost equal amount of slag which in its raw condition

is a pure waste product and for which there is no sale, becomes a serious matter, the more so in a large city like Pittsburg where waste lands are scarce and expensive.

The Americans have been either more ingenious or more fortunate than ourselves in meeting this difficulty, and the ugly banks of slag which so disfigure the landscape in our iron districts are of comparatively rare occurrence in the United States.

The chief uses to which iron blast-furnace slag is put in America are: in the manufacture of cement; as railroad ballast; and for filling in uneven ground in the neighbourhood of the works.

In either case the slag is first granulated by bringing it into contact with water while still molten. At Cambria the cinder is run in a constant stream on to a series of shallow plates carried on an inclined plane by a revolving endless belt. As the plates are carried upwards they receive a spray of cold water which granulates the slag, and this is dropped, as the plates turn over, into cars standing below ready to receive it. It is then in condition to be finely ground, mixed with sand and lime, and strongly heated to form a cement; or it may be employed directly for filling-up purposes.

At the furnaces in the Mahoning and Shenango Valleys, the slag is largely sent away for railroad ballast, and a very cheap method of handling it is in operation.

Placed in close proximity to the furnace is a round water-tank built some 20 ft. into the ground and about 10 or 20 ft. in diameter. Into this leads the slag runner from the tapping-hole, and as the slag runs in, there pours over it a heavy stream of cold water which thoroughly envelopes the descending stream of slag.

Perfect granulation is effected, and the product is raised from under the water on to railroad cars by a small crane operating a clam-shell bucket. Perforations in this clam-shell allow the water to fall back into the tank, and the

slag soon dries owing to the great amount of heat which it still retains.

The cost of the entire handling of the slag in this way was stated at one furnace to be 5 cents per ton; in this case tank and furnace were separated by a considerable length of slag runner, all of which had to be kept clean by hand-labour. Where conditions are more favourable, the cost need not be more than 2 cents per ton.

The blast-furnace plants described so far have been integral parts of large steel works, where the product of the furnace has undergone further treatment.

But on the border-line of Pennsylvania and Ohio, between Pittsburg and Cleveland, and centreing about Youngstown, Ohio, are a number of furnaces which are producing pig-iron for the open market. They are independent of any of the larger firms and of the Trust, and are known as the valley merchant furnaces, from the Mahoning and Shenango Valleys in which they are situated.

It is interesting to compare these in point of equipment and output with those belonging to the larger concerns.

One plant consisted of a single furnace 76 ft. high, provided with five hot-blast stoves, some 2-pass, some 3-pass, ranging in height from 60 to 80 ft. A soft product of Bessemer iron, analysing:—

Silicon		1·00%
Phosphorus	below	0·100%
Sulphur	„	0·050%
Manganese	about	0·80%

was being smelted from a mixture of 87½ per cent. of high-grade soft ore (iron content 63-64 per cent.) and 12½ per cent. of low-grade, hard, silicious ore (iron content 40 per cent., silica 40 per cent.). The iron in the mixture averaged 56 per cent. The burden was as follows:—

Coke	7,600 lbs.
Lime	5,240 lbs.
Ore	16,000 lbs.

and the output averaged 300 tons a day.

About 3 per cent. of the ore charged is carried away in the form of dust, and is recovered, by means of a grab-bucket and crane, from a tank into which it is washed down with the water from the dust catcher. The latter also takes care of the slag, which is treated at this works by granulation, as already described above.

The cost of manipulation was stated to be 2 cents per ton.

The plant was provided with three Wheeler and four Stirling water-tube boilers, all fired by gas (of which there is an excess), and they are capable of raising steam for 5,000 h.p.

The blowing-engines, each costing $20,000, were by Weimer, of Lebanon, Pa., one a spare engine for emergencies.

The temperature carried was 900°F., and the blast was maintained at 35,000 cubic feet of air per minute.

The furnace had only one bell, was hand-filled, and was provided with the usual vertical hoist. The pigs were cast in sand, and broken and piled by black labour.

The labour cost of 70—90 cents per ton of iron produced compares favourably with that at plants where there have been large outlays on labour-saving appliances. The management expressed the opinion that competition with the larger plants was largely possible because in the smaller concerns, cost of repairs and interest on investment were very much less.

Moreover, these furnaces can smelt a larger proportion of fine ores with greater freedom from explosion and loss of material than can the Pittsburg furnaces. Even here, however, the actual loss of material is considerable.

Of technical rather than of economic interest, are the

details of a furnace in this same district working on a special quality of low-phosphorus iron for the acid open-hearth furnace. In such a case, quality rather than quantity of output is the more important; and the plant in question, a 75 ft. furnace, was making about 220 tons per day. A high temperature in the blast-furnace produces a high-silicon, low-sulphur iron, and a low temperature a low-silicon, high-sulphur iron.

In order to obtain a product low in both elements, it is necessary to blow "cold," and to have a large proportion of lime to remove the sulphur.

The temperature carried in this instance was 800°F., and the blast-pressure about 9 lbs. per square inch (25,000 cubic feet per minute). Ores very low in phosphorus were employed exclusively, and a specially pure lime was hauled all the way from Tyrone in Central Pennsylvania.

The East. The furnaces of the East will have to be treated under two heads—firstly, the older furnaces, which, built a considerable time ago for the smelting of local ores, mainly with anthracite fuel, have come to be dependent, for reasons already cited, upon supplies of both ore and fuel removed at a considerable distance. These constitute in numbers of furnaces, if not in output, the greater part of the blast-furnace plants of the East; secondly, those comparatively few furnaces, whose situation in close proximity to plentiful supplies of good ore gives them a peculiar advantage in respect of this raw material at any rate, and differentiates them from the general class of Eastern furnaces.

This distinction is important; and when it is stated that the furnaces of the East are far behind those of the Pittsburg district and of the majority in our own country, in their capacity for economic iron production, the plants at Wharton, New Jersey, at Port Henry, New York, and at Lebanon, Pa., which fall into the second category, are expressly excepted.

A number of furnaces in or near Harrisburg are operated in conjunction with adjoining steel works where the greater part, if not the whole of the raw product is consumed. This is also the case with the furnaces at the Bethlehem steel works, and, to some extent, with the two plants at Lebanon.

With these exceptions, however, the plants in the East form a group with fairly well-defined characteristics, producing generally basic- or foundry-iron for the open market. The conditions by which this industry is surrounded have already been discussed. The practice adopted differs materially from that in Pittsburg and the West.

In the matter of fuel, a mixture of coal and coke is almost universal. The proportions vary at different works, but it would be safe to say that those employing more coal than coke are in the minority. The coal lies comparatively near to the greater number of furnaces, in the anthracite field of Eastern Pennsylvania. The coke, on the other hand, requires hauling from Altoona, Connelsville or West Virginia.

Coke requires more delicate handling than coal, and the higher freight rate thus involved, combined with a greater length of haul, and a higher initial cost of coke, renders the difference in cost of fuel at the furnace in favour of coal, considerable. A purely technical advantage which results from the admixture of a proportion of coal with a coke fuel, is the improvement in the burning quality of the furnace gases. This device is resorted to at the Colebrook furnaces at Lebanon which are working on hard Cornwall ore and where there is a shortage of steam. One barrowful of coal to every sixteen of coke is found to improve the gas for the boilers very materially, and this proportion of coal is increased when the shortage becomes serious.

"In the matter of ores, Pennsylvania, which until 1880

was the largest ore-producing State in the Union, has now (1903), concurrently with the working out of the best local ores and the advent of Lake ores, enjoying a cheap transportation, sunk to seventh place among the ore-producing States, and boasts only two mines with an annual output of more than 50,000 tons."

The details of ore production in Pennsylvania for the year 1903 are as follows:—

	Long Tons.
Red Hematite	15,420
Brown Hematite	202,542
Magnetite...	426,637
Total	644,599

Of this total 401,470 tons came from one mine, the historic magnetite ore bank of Cornwall, and was all smelted either at the three furnaces on the bank itself, or at the two plants at Lebanon, four miles distant.

The place of the local supplies of raw material has been taken largely by Lake Superior, and (but to a much smaller degree) imported (Cuban) ores. The red and brown hematites of the neighbourhood are in many cases practically free from sulphur and serve admirably, therefore, for the making of foundry iron.

The Cornwall ore, on the other hand, is almost equally free from phosphorus, and therefore lends itself to the smelting of good Bessemer pig. The high percentage of sulphur in the raw ore can be very largely reduced by roasting, prior to charging it into the furnace.

Generally speaking, a mixture of several kinds of ore, or of ore and cinder, is used at these furnaces.

At one works, the proportion of Lake ores used is 25 per cent., the remainder being red and brown hematites and the magnetite just mentioned. In another case, the enricher of the local ores is a Cuban ore.

One furnace smelts Lake ores exclusively.

Equipment. The furnace stacks vary in height from 60 ft. at the oldest to 85 ft. at the most recently erected plants. A 70 ft. furnace equipped with 8—10 tuyeres, a single bell, a covered cast-house with sand pig-beds, blowing 25,000 cubic feet of air per minute (equal to a blast-pressure of 7—9 lbs) at 800°—1,200°F., and making an output of 120 tons a day, is typical of this group.

In one respect the furnaces are well-equipped, namely, in blowing-power. This is, to the American blast-furnaceman, a first essential, and there is scarcely a furnace which has not, in addition to the engines in ordinary use, a duplicate engine to each furnace for use in emergencies.

Little advance has been made in the substitution of machinery for labour. The skip-hoists have not yet taken the place of the hand-filled barrows and vertical elevator, nor the pig-casting machine of the old method of casting in sand and lifting by hand. There are no such elaborate methods of handling and stocking ore as those described in connection with the furnaces of the West; and the slag is manipulated by casting on to boxes on cars, cooling, stripping and dumping in the old-fashioned way.

The tapping-hole stopping-gun is the only labour-saving device in general use.

The labour on a 70 ft. furnace making foundry iron from a 52 per cent. mixture, and turning out 1,000 tons a week is:—

12 mine-fillers.
2 top-fillers.
4 pig-lifters.
6 men in cast-house.

The barrow-fillers receive $1·60, and the men in the cast-house $1·60—$1·90 per day.

They work in two shifts, of 12 hours each, or of 10 and 14 hours respectively.

Day labourers receive $1·10 for a 10 hours day.

Depending on the capacity of the furnace, the richness of the ore mixture, the proportion of coke to coal in the fuel, and the quality of product aimed at, the outputs vary from 90 to 300 tons per furnace per day, though the latter figure is very high for this district. The average will probably lie between one and two hundred tons.

The practice differs, of course, according as foundry or basic iron is to be made. In the latter case, while a heavier burden can be carried, the temperature must be kept down in order to insure a silicon-content of not more than 1 per cent., and the temperature rarely exceeds 900°F. The general requirements for a basic iron are:—

Silicon	below	1·00%
Phosphorus	,,	0·700%
Sulphur	,,	0·050%

A blast-pressure of from 5—8 lbs. is usual, although a constant volume of air is more important for steady working than a constant pressure.

While the higher temperature carried for foundry irons (1,100°—1,200°F.) ensures the greater part of the sulphur being absorbed by the cinder, it is usual in the best practice to employ none but sulphur-free ores, since the fuel alone will give rise in the product to from 0·015—0·030 per cent. of that undesirable element.

For poorer grades of foundry irons and for forge irons, use can be made of a cheap local ore rich in iron, but containing a high quantity of sulphur-bearing pyrites. This ore admits of being very cheaply roasted in a Gjer's calciner, the pyrites being sufficient to maintain combustion, and in this way a large proportion of the sulphur is removed. It is then available to a limited extent for admixture with high grade ores in the furnace.

The following data exemplify the practice in low-

sulphur foundry-pig-iron production at a furnace in the Lehigh Valley in March, 1904:—

Ore Mixture	25% Lake Ores (62% Iron)
(52—54% Iron)	25% Magnetites (60% „)
	50% Hematites (40% „)

Fuel	25% Anthracite Coal.
	75% Connelsville Coke.

Fuel consumption, 2,500 lbs. per ton of iron produced; blast-pressure, 8—9 lbs.; temperature, 1,150°—1,200°F. The product of a 70-ton furnace equalled 1,000 tons a week.

The plants at Lebanon, as already mentioned, differ from others in the neighbourhood in smelting exclusively ore from the famous Cornwall bank, and in making a product of Bessemer pig. The latter fact is the direct result of the quality of Cornwall ore. These plants include in all nine furnaces—two at the North Lebanon plant, belonging to the Pennsylvania Steel Company of Harrisburg, four at the Colebrook plant, and three on the ore bank itself, the latter now all owned by the Lackawanna Steel Company, of Buffalo.

Of the furnaces at North Lebanon, one is a typical modern furnace 100 ft. high, with sixteen tuyeres, two bells, equipped with skip-hoist and four three-pass Massick and Crook stoves; and it is capable of making 250 tons of iron a day from a 45 per cent. Cornwall ore.

This furnace was not in blast in February, 1904.

Together with the gas roaster it has already been fully described (" American Industrial Conditions and Competitions ").

The second furnace is more modest, being 80 ft. in height and having a blast-pressure of 9—11 lbs. per square inch. The output is only 150 tons per day.

After roasting for 24 hours with soft coal in either

Gjer's calciners, or the gas-heated roaster already referred to, the 3·0 per cent of sulphur in the crude Cornwall ore is reduced to 0·7 per cent. The phosphorus in the ore averages 0·09—0·11 per cent., and in the pig 0·05—0·07 per cent. The fuel consumption is 32 cwts. per ton of iron, coke being used exclusively. The latter analyses:—

Sulphur	0·75%
Ash	11·0%

The blast-pressure varies from 9—11 lbs.

In order to bring down the sulphur in the pig to 0·020 per cent. a high temperature is carried, often reaching 1,250°F., with the result that the iron contains from 1—3 per cent. of silicon. This is much in excess of the general Bessemer practice in America.

This furnace is also filled by skip-hoist, and has a very efficient modern equipment for blowing-power.

Considering the hardness of the ore worked, its comparatively low content of iron, and the sulphur difficulty which has to be contended with, this furnace is doing good work. The product is all manipulated by a Uehling pig-casting machine, operated by four men. The manager expressed himself as very much in favour of this method of handling pig, and satisfied of its well-proved economy.

The furnaces at the Colebrook plant are not of such recent construction as the one just described, although they have undergone considerable modifications from time to time, and have a present output of 120 tons a day. Of the changes recently made, a significant one is the equipment of the boshes with a water-cooled steam-jacket, which the present manager much prefers to the bronze cooling-boxes let into the furnace-lining, which are such a feature of the giant furnaces of the West.

The plant is being brought up to date by the erection of a battery of four 250 h.p. Cahall boilers in place of the old tubular boilers.

In contrast with the skip-hoist at North Lebanon, the furnaces here are hand-filled. The relative merits of the two methods will be discussed shortly.

In one respect, the Colebrook plant is at a disadvantage as compared with its rival. When both the furnaces at North Lebanon are in commission, the whole of the ore is roasted by means of blast-furnace gas, and the only charge, in addition to an insignificant one for interest and depreciation, is that of handling.

At Colebrook a modified form of Gjer's calciner is employed, and the cost of roasting with small coal is 36 cents per ton of ore.

The two furnaces are 75 ft. and 80 ft. in height, with hearth diameters of 11 ft. and 12 ft. respectively. Seven blowing-engines, making 30 revolutions per minute, and each capable of blowing 500 cubic feet per revolution, maintain a blast-pressure equal to 25,000 cubic feet of air a minute.

The coke is made on the spot in by-product ovens, 220 in number. The mountain coal used contains 4 per cent. of sulphur, which, after the coal has been washed, is reduced to 2 per cent., and amounts to 1·4% in the coke. After crushing and washing, the coal is conveyed on a travelling belt to a large bin, whence it is discharged into a machine which compresses it, after moistening, into a large cake, and deposits it in the oven. From three and a half to four tons of coal are charged into each oven, and the coking period averages 35 hours. This period it is expected to reduce. Only coal-tar and ammonia are recovered, the gases being then sent back to heat the ovens. The product is a good hard coke, but on account of the coal used, is high in sulphur.

The plant of the Port Empire Iron and Steel Co., Catasauqua, Pennsylvania, offers a good illustration of furnaces, which, built two or three decades since, are now under all the disabilities which that statement implies;

they are striving to maintain their position alongside the giant furnaces of the West, which, springing up almost daily, embody the latest principles of blast-furnace construction and practice.

The plant consists of three blast-furnaces, two of 70 ft., making 1,000 tons a week, and one of 65 ft., making 600 tons a week, of foundry iron. The blast-pressure and temperature carried are $8\frac{1}{2}$ lbs., and 1,150°—1,200°F. respectively.

The ore mixture consisting of about one-quarter of Lake hematites, and the remainder New Jersey magnetites, local hematites, Port Henry, calcined, and concentrated ores, has an average iron-content of about 50 per cent.

Thus, two tons of ore have to be put through the furnace to produce a ton of iron. The fuel consumption is 2,500 lbs. of coal and coke combined per ton of iron. The coke, which forms 75 per cent. of the fuel charged, is hauled from Connelsville, Altoona, and West Virginia; the anthracite is situated only some 100 miles distant, at Scranton, Pa.

The blowing-engines are of the large beam type, and date from 1856 and 1866 respectively.

The old-fashioned pipe-stoves are still in use at this works for the older furnace, and this was the first plant of hot-blast stoves to be erected in the United States. The other furnaces are provided with stoves of a more modern pattern.

The pig is cast in sand beds, and removed by hand.

In comparison with some of the furnaces already described, the amount of labour employed here appears very high, the crew on each furnace consisting of two top-fillers, 12 bottom-fillers, 6 men on the furnace front, and 4 pig-lifters.

Such are the general features of the industry as carried on by the merchant furnaces in Eastern Pennsylvania.

With the diminishing importance of local sources of supply, this industry has come to depend to a very great extent on raw materials removed, in one case 1,000 miles, and in another 500—700 miles, from the furnaces. It labours under the further disadvantage of small outputs, and plants whose equipment is not the most modern. Against these can be set no cheap supply of labour such as the furnaces of the South enjoy. The one advantage which these furnaces can claim is proximity to the markets of the East.

On the other hand, in the economic world, success is the only guarantee of existence; and the fact that this industry has in the past, and, what is more, continues in the depressed present, to fairly hold its own, leads one to compare and contrast its condition with those of the more favourably situated industry in the middle West.

Possibly the two districts are not in effective competition.

With regard to the relative advantages of large and small furnaces and of skip- and hand-filling respectively, it is the practice in the United States Steel Corporation to encourage a healthy competition among the blast-furnace managers of the various constituent works.

The result of such competition in bringing down costs of production has proved that a hand-filled furnace 80 ft. or 85 ft. high is the most economical furnace which has yet been built.

The labour charges on a modern skip-filled furnace are of course less than in the case of hand-charging. On the other hand, particularly in working with the fine Mesabi ores, skip-filling leads to uneven filling of the ore, and the charge is liable to work down one side of the furnace. Any irregular working adds 2 or 3 cwts. to the coke consumption per ton of iron produced. The slipping which is so common with high hard-driven furnaces also means a reduced output through irregular working and through loss of material.

The advantages are therefore not all on the side of the "modern" plants, as they are termed. A more moderate rate of working also allows that greater control over the product of the furnace, which is essential in the making of good foundry iron.

The East enjoys a small advantage over the West in the matter of wages.

The following details of costs of production, supplied by a blast-furnace manager from his working note-book, in the manufacture of foundry iron and of basic iron by two different furnaces in the East, will be more eloquent of the possibilities of pig-iron manufacture in that district than many pages of descriptive matter.

Cost of Manufacture of Foundry Iron at Furnace in Eastern Pennsylvania, for week ending March 3rd, 1894 (furnace working on Cornwall ore and mill-cinder for the production of foundry iron):—

Material.	Amount used in tons per ton of iron produced.	Price. $	Cost. $	Total amount used in tons.
Coal	0·94 @	2·51	2·35	435
Coke	0·51 @	2·75	1·40	233
Ore	0·44 @	1·90	0·84	198
Cinder	1·32 @	1·30	1·72	596
Lime	1·04 @	0·65	0·68	468
Labour	—	0·89	0·89	—
Office	—	0·28	0·28	—
Weighing pig-iron	—	—	0·70	—
Fixed charges (not included, since the furnace was being worked for a preferred creditor)	—	—	0·25	—
Total cost of iron per ton	—	—	9·11	—
Total product for week	—	—	—	450

(1 ton = 2,268 lbs., 28 lbs. per ton being allowed for sand.)

The last table referred to production at a time of great depression, if not of panic, in the United States iron trade. Labour was therefore cheaper than usual, and the cost of production can scarcely be called normal. It shows, however, what can be done.

Cost of Manufacture of Basic Iron at Furnace in Eastern Pennsylvania for week ending December 21st, 1895 (the furnace was working on Lake ores and heating-furnace-cinder, the iron to analyse):—

Silicon	below	1·00%
Phosphorus...	„	0·700%
Sulphur	„	0·050%

Material	Tons per ton of iron.		Price $	Cash $
Coal	0·55	@	2·70	1·48
Coke	0·59	„	3·03	1·78
Cinder...	0·86	„	2·00	1·72
Vermilion ore	0·67	„	3·95	2·64
Hematite ore	0·16	„	3·50	0·56
Lime	0·78	„	0·51	0·40
Labour	—		—	1·25
Management, Supplies and repairs	—		—	0·75
Total cost of production per ton				$10·58

Product for the week 586 tons. The large proportion of mill-cinder used made the fuel consumption higher than usual.

To complete the account of the Eastern industry, it remains to describe one of the works belonging to that second small group of plants mentioned on p. 76.

The Wharton plant at Port Oram, N.J., consists of three blast-furnaces in all. Of these, the oldest was working at the time of the writer's visit on foundry iron, and does not call for any special consideration.

The two more recently erected structures had the following dimensions: Height, 100 ft.; diameter (boshes), 21 ft.; diameter (hearth), 14 ft.; number of tuyeres, 16; air-blast, 42,000 cubic feet per minute; temperature, 1,100°F.; output, 450 tons per day.

The furnaces were working on basic iron, and since the ores are sulphur-free, there was no occasion to keep down the temperature.

The burden was 21,400 lbs. ore, 12,000 lbs. coke.

This plant was working on New Jersey magnetites exclusively. The ore is found at Hibernia, about 12 miles distant, in a seam 7—8 feet thick, and is mined underground by drilling and blasting.

It then undergoes concentration at the mine head, and the product is worth about $2 per ton.

The raw ore contains 45—52 per cent. of iron. It is concentrated up to 59—62 per cent. of iron.

There are two varieties of concentrates—" lump ore," in pieces of about 2 in. diameter, and " fines." The latter is treated as a separate ore, and cannot, on account of its dusty character, be used to a greater extent than about 12 per cent. of the total charge. It has none of the binding properties of Mesabi ore, and gives great trouble in slipping.

The lump ore is extremely hard, and the life of a furnace-lining smelting it is correspondingly short. One of the furnaces of this plant required repairing after a twenty-seven months' run.

The fuel employed is a Western Pennsylvania mountain coke, dusty, and of not very high quality. It is well adapted, however, for standing the burden of 100 ft. of hard ore.

The arrangement for cooling the boshes was a series of bronze cooling-boxes, such as are employed in the large furnaces of the West. Generally speaking, the steel cooling-plate is in favour in the East, and the bronze cooling-boxes in the West. It has been seen, however, that boxes were the cooling device adopted in the reconstruction of the Lebanon furnaces; while it is noteworthy that cooling plates are in use at the furnaces of the Pennsylvania Steel Co., at Harrisburg, and a modified form of the same device at the Ohio steel works, Youngstown, Ohio, which comprises some of the largest furnaces in existence. But, as the manager of the Wharton plant pointed out, the Harrisburg furnaces are small, and

a real comparative test yet remains to be made between the two arrangements as applicable to large furnaces. The furnaces are filled by means of skip-hoists charged from bins. Two men on a single electric larry fill and weigh all the material for one furnace, and one man on the top operates the hoist and bells. Steam, not electric power, is employed in this latter operation.

A Uehling casting-machine has given fairly satisfactory results, but it is found that very frequent repairs are necessitated. The wheels of the mould wear down the rail; and the moulds themselves, being fixed at both ends, have no room to expand and contract with changes of temperature, and are constantly cracking. They have to be replaced at the rate of one a day. A simple modification has accordingly been devised, whereby the moulds are placed in the same direction as the travelling belt, instead of across it; and this arrangement allows of their being attached to the belt by one of their ends only. There is thus perfectly free play for the forces of expansion and contraction in the mould.

The Concentration of the Ore. Two methods of concentration are in use for enriching the ore, both depending upon the attraction of an electro-magnet for the pure magnetite and the rejection by the same of non-magnetic particles.

In the older method, the ore as it comes from the mine in lumps is hand-picked upon a slowly-travelling belt and divided into two parts. The first consists of large lumps of ore containing about 52 per cent. of iron, which are sent to the furnace and smelted directly.

The rock which is thrown out, and which was formely rejected as valueless, contains on an average 28 per cent. of iron, and is now subjected to further treatment. It is crushed and cobbed, and then passed over two drums, in the interior of which are strong permanent magnets. The pure magnetite is retained momentarily on the second

drum, thrown off from that on to a travelling belt, and delivered into car.

The pure sand drops off the first drum, and is also collected.

The "middlings," that is, the lumps which still contain both magnetite and sand, are carried half-way to the second drum and then thrown off. They are re-crushed and re-treated.

Somewhat less than half the original residue is obtained as ore, but it has an iron-content of 62 per cent. The cost of treatment of such an amount of residue as will yield one ton of these rich concentrates is $1·10. The sand separated in this process is very pure, and is in great demand for cement manufacture. It commands a price sufficient to cover the cost of operating.

The newer method which it is proposed to instal altogether consists in first grinding all the ore mined until it will pass through a 2 in. mesh.

The whole is then passed over Ball-Norton two-cylinder magnets, which differentiate it into lumps of pure magnetite, and lumps of impure magnetite. (The latter may consist of as much as 50 per cent magnetite.)

This second half is then re-crushed and treated as before, when a further crop of pure magnetite, in lumps of smaller size, is obtained.

By this method there are obtained from the original ore about six parts of magnetite (containing 59—60 per cent.), and about four parts of sand (containing still about 10 per cent. of magnetite).

The cost of operation is only 10 cents per ton of finished magnetite, whereas in the former method 28 cents per ton were consumed in hand-picking alone. About 100 tons of mined ore are operated daily at the present time.

CHAPTER V.

The Manufacture of Steel and of Rolled Steel Products.

THE greater part of the pig-iron converted into steel in the U.S.A. is purified by the acid Bessemer or the basic open-hearth process. The acid open-hearth process finds employment in the production of a small amount of high quality medium-carbon steel for special purposes, such as the manufacture of car-wheels, springs and axles.

The small tonnage of crucible steel is more than counterbalanced by the extremely high quality of the high-carbon steels and special alloys which are produced by the crucible process for use as cutting tools and for cutlery purposes. The high prices obtained and the amount of skilled labour employed, give this branch of the industry an importance out of all proportion to its size as measured by tonnage of product.

The reasons for the preponderance of the two first-mentioned processes, and for the non-existence of a basic Bessemer industry in America have already been analysed in a previous chapter. It remains to add that the proportion of steel manufactured by the Bessemer, to that manufactured by the open-hearth process, is, consequent upon the death of old-fashioned prejudices against open-hearth steel, and the more general acceptance of the basic product for constructional work by engineers, on the increase.

The outstanding feature of the production of raw steel and rolled-steel products, as of pig-iron, is the rapidity

of output which characterises it. In analysing the causes of this phenomenon, it becomes evident that the result has been attained in two kinds of ways—by increasing the efficiency of the industrial organisation and by modifying the technical processes formerly in use.

Under the first head are to be considered (1) the close combination between pig-iron and steel-smelting plants, (2) the employment in Bessemer converters and open-hearth furnaces of molten pig-iron direct from the blast-furnace, (3) the equalisation of composition of the products of a number of furnaces effected by means of a pig-iron mixer, (4) ingot-casting on cars, (5) the employment of mechanical charging-machines for open-hearth furnaces, and (6) the large replacement of hand labour by machinery in rolling-mills.

Under the second head will come (1) the use of low-silicon iron in the Bessemer converter, and (2) the cheap supplies of natural gas available in the Pittsburg district.

The steel plant not equipped with its own blast-furnaces is, except in the case of those works devoted to the manufacture of a single speciality or of a number of products of high grade steel, almost unknown in America.

The Cambria, the Pennsylvania, the Ohio, the Duquesne, the Homestead, the Lackawanna, the Maryland, the Edgar-Thomson, and the Jones and Laughlin's steel works are all provided with their own blast-furnaces. Even the Bethlehem steel works, which turns out such a speciality as armour plate, is independent of outside sources for a large part of the raw material for its open-hearth furnaces.

The advantages of such a close combination of the two branches of the industry are: a greater control by the steel smelter over the iron which is his raw material; and the saving of a large amount of heat-energy which would be lost were cold iron to be used in steel-smelting. The value of such combination has been strikingly exhibited in the rapidity of production which this arrangement has

rendered possible in the domain, particularly, of Bessemer converting.

Against these advantages must be offset the inelasticity of a blast-furnace plant, which may not be able to help out a shortage of pig-iron at a time of boom in the steel trade, and on which standing charges have to be paid in a time of slackness.

From this it would appear that, in view of the considerable fluctuations which take place in the demand for pig-iron, a plant of three small blast-furnaces would possess advantages in the direction of elasticity not found in a plant of equal capacity comprising only two furnaces of larger size. Whether such advantages would be more than offset by the greater running charges in normal times would appear, from the non-existence of the system, to be answered in the positive. And in the largest plants, comprising ten or a dozen furnaces, the margin of elasticity spoken of may be served by even a 90 ft. or 100 ft. furnace.

The iron as it comes from the blast-furnace in ladles is carried to a pig-iron mixer, with one of which almost every large works is provided. These are in reality a kind of open-hearth furnace of the rolling type, varying in capacity from 75 to 300 tons. In some cases they are kept hot by burning in them producer or natural gas, in other cases the metal itself is considered sufficient to maintain the temperature.

The mixer receives the successive charges of pig-iron generally through a small hole in the top, the ladles of pig being elevated by electric overhead travelling cranes and then overturned.

For discharging its contents, the mixer is provided with an arrangement similar to that found in a tilting open-hearth furnace, viz., a chute down which the metal flows when the furnace is tilted.

The labour on a mixer is small, comprising in many cases only a couple of men.

Doubtless the repairs item is considerable, but the advantages of a continuous supply of hot metal of practically constant composition, which the employment of a mixer ensures, are enormous.

Another feature of the large steel works which makes for regularity in working and the prevention of delays, is the system of casting ingots on cars.

Instead of the old arrangement of a casting-pit with ingot-moulds fixed in position on steel blocks on the floor, and filled from a ladle moved round the pit at the extremity of a circular-crane arm, the ingot-moulds are now placed on low cars which themselves form the base of the moulds, and are filled from a ladle dependent from an overhead travelling crane. The ladle quickly moves from one mould to another, and as soon as a train load of ingots has been poured, it can be drawn away and taken right out of the casting-house. The great radiation of heat from cooling ingot-moulds and from stripped ingots, and the confusion caused by the necessary delay in stripping ingots and by refractory ingot-moulds which offer difficulties in removal, are now all avoided by the new method.

The train load of ingots is taken out into the open air, placed on a siding for a short period until the metal has solidified, taken to the stripping-house, and the mould removed by machinery, leaving the ingot standing on the car. The train of stripped ingots now proceeds to the soaking-pits. The moulds as they are removed from the loaded cars are set down upon a train of empty cars standing in a parallel line, and soon a train full of empty moulds is ready to be taken out into the open to cool down, and then to the cast-house again to be filled.

Each mould and each ingot receives only one handling under the new system in place of two under the old. Moreover, in a Bessemer shop with three or four converters, each producing 10—15 tons of metal every 12—15 minutes,

clockwork regularity in the casting and stripping and removal of ingots is of the utmost importance.

An eminent American steel metallurgist has stated that large outputs in that country are due, not to actual very rapid working, but to the avoidance of delays and stoppages.

It is just this freedom from delays which the car-casting of ingots confers that has been the chief element in its successful application.

The charging-machine is now, and has been for a number of years an integral part of the open-hearth plant in America. Indeed, the present author does not remember to have seen, in some thirty or forty works which he visited, a single open-hearth plant of the usual type without its mechanical charging-machine.

These are mostly of the Wellman type, and of several patterns according to the room available for them. One machine is generally supplied to each four or six furnaces, but at the new open-hearth plant at the Cambria steel works, a single machine takes care of ten 50-ton furnaces.

As showing the value attached to this form of labour-economiser, a charging-machine has been installed when only a single 50-ton furnace had to be filled.

A description of the system of mechanical charging which the introduction of the Wellman machine inaugurated is almost superfluous at this time, and will be simply outlined.

Unskilled labourers weigh out and pack on iron boxes standing on railway cars in the yard, the requisite materials for an open-hearth charge. A number of these cars are hauled by locomotive to the platform of the open-hearth furnaces on rails which run between the latter and the charging-machine. The arm of the machine then lifts up the boxes, thrusts them into the furnace, overturns, withdraws, and finally replaces them on the cars. In the vicinity of the furnaces, the cars themselves are also propelled by means of the machine.

The economies effected lie not only in the arduous hand-labour which would otherwise be required, but in the greatly reduced period of charging, and the reduction in loss of heat through the open doors.

Five-sixths of the time necessary for hand-charging has been saved by the agency of this machine.

The rapidity of production of Bessemer steel in America is undoubtedly due in large measure to the greater purity of the iron converted. It has already been pointed out (Chapter I.) how the chief source of heat in this process lies in the oxidation of the impurities, and chiefly the oxidation of silicon which has to be removed from the iron, and how, consequently, the percentage of this element in the molten pig must not fall below a certain figure, about 0·9 per cent.

Even with an iron containing 1 per cent. of silicon, the greatest care has to be taken that the metal does not "freeze" in the converter. But by dint of rapid charging and discharging,—and in this matter the system of ingot-casting on cars has been of invaluable service,—and by so arranging the converters that they lose heat chiefly to each other, the American steel smelter is able to work down to a very low content of silicon,—about half that considered necessary in a Bessemer iron in this country.

The records achieved speak eloquently of the time-saving which this modification in a technical detail has effected.

The Edgar-Thomson steel works at Bessemer, Pa., near Pittsburg, one of the constituent companies of the Carnegie Steel Company, and of the United States Steel Corporation, is chiefly engaged in the various processes leading up to the production of rails.

The Bessemer converters are supplied from eleven 100 ft. blast-furnaces, ten of them turning out a product of Bessemer iron, the eleventh working on ferro-manganese. They blow 11—16 lbs. pressure at 800—1,100°C., and turn

out 650 tons per furnace per twenty-four hours. Strange to say, no metal mixer appears to be used at this plant.

The converter-house itself contains four 18-ton converters. They are controlled by two operators, one to each pair of converters, who occupy a position of vantage on the "pulpit" or elevated platform at the other side of the converter house and thus command a complete view of every part of the mill. The metal is conveyed to the converters in ladles running on rails at the back of the converters. In front of the latter is the ladle on a crane which receives the steel and discharges it into ingot-moulds standing on cars on the floor of the shop.

The total labour in such a shop, in addition to the two men already mentioned, consists of one man to regulate the charging of the pig-iron and ferro-manganese into the converter; three men to cast the metal into ingots; one man to spray the ingot-moulds with lime-water; and two men to clean up the metal spilt over the tops and sides of the ingot-moulds.

The ingots are carried away to two pairs of hydraulic strippers and placed in soaking-pits. These differ from our own in being generally built, wholly or partly, above ground. They are fired with natural gas, and are fitted with sliding tops operated hydraulically.

The converter-house of the Duquesne steel works at Duquesne, near Pittsburg, is run on much the same lines as the one just described. The plant consists of two converters blowing 10-ton charges at an average rate of eleven minutes each. On the day previous to the writer's visit the production of the two converters had been 2,400 tons of metal, and only fifty minutes had been lost in delay. The average monthly production at that time was 2,200 tons in twenty-four hours.

These rates of production of Bessemer steel are not exceptional. For example, 12-ton converters at the Cambria steel works were blowing each 600—700 tons of

metal in an eight-hours turn, and the average period of blow of about the same quantity of metal in the Bessemer shops of the Homestead steel works at Pittsburg, and the Lackawanna steel works at Buffalo, was twelve minutes in each case.

The raw material is supplied from a 300-ton mixer, itself taking 75 per cent. of furnace iron, and the remainder from cupolas which are requisitioned to make up the deficiency in blast-furnace capacity.

Besides pig-iron, the converters receive a small charge of solid scrap-steel, the addition of which, while necessitating a somewhat longer blow, reduces the 1·23 per cent. of silicon in the pig-iron, and lessens the wearing action on the lining.

The ladles into which the converters are discharged are supported on the arm of a crane in such a way as to have a lateral motion along the same, while the crane itself possesses both a rotating and a vertical motion.

The steel is cast into 2½-ton ingots on cars, and the stripping takes place in a separate shop. The movement of the cars under the hydraulic strippers is effected quickly and accurately by means of a rod running alongside the rails which can be turned to catch the cars and push them backwards or forwards. This rod is also worked hydraulically and is under the control of the ingot-stripping operator.

One of the causes of absence of delay in Bessemer blowing is the excellence of the arrangements made for the rapid repairing of converters while in commission.

As soon as the converter is turned down horizontal, an overhead travelling crane quickly removes the bottom of the converter and a couple of men, on a platform provided for the purpose, are busy examining the tuyeres and replacing defective ones almost before the metal has been poured. By the time the converter is re-charged, the repair work is complete, the bottom has been swung into

position and wedged in, and the blowing proceeds apace without a moment's delay.

The Bessemer shop of the Pennsylvania Steel Company's works at Steelton, Pa., is an example both of compact arrangement and of the rapidity and ease of working which seems to be directly proportional to the extent to which labour has been replaced by machinery.

It comprises: two converters of $9\frac{1}{2}$ tons working capacity together with three cupolas for melting spiegel, placed all in one line; behind these, a 75-ton metal mixer, through which passes the molten pig-iron from the blast-furnace; three ladles depending from overhead travelling cranes, for pig, spiegel and finished metal respectively; and the ingot-moulds on cars on the floor of the house in front of the converters.

The converters turn out each 50—70 heats of $9\frac{1}{2}$ tons in an eleven-hour turn in twelve-minute blows. A steel for street-car rails (carbon, 0·25—0·60 per cent.) was being made at the time of the author's visit, and 1,700 lbs. of spiegel were added to every 19,500 tons of metal.

The labour employed consists of three men on the mixer, one on each crane, one running-out and weighing the spiegel, one controlling the two converters, and a few labourers clearing up the scrap and cinder, and helping in the casting of the ingots.

The greater part of the steel made by the Bessemer process goes to the construction of rails of all kinds. The chief exception to this statement which came under the writer's notice was at the Cambria steel works at Johnstown, Pa., where a large quantity of structural shapes was being rolled from Bessemer ingots.

In the matter of rapidity of production, the open-hearth process is as much ahead of the English practice as is the case with Bessemer converting. The record for an acid open-hearth furnace at the Standard Steel Works, Burnham,

Pa., making 55 tons of metal was 5 hours 36 minutes from the time of completion of charging to time of tapping.

One of the causes is the same as before, viz., the greater purity of the iron employed. An average composition of American basic iron (it will be remembered that American open-hearth furnaces are chiefly basic lined) is:—

Phosphorus	below	0·70%
Silicon	„	1·00%
Sulphur	„	0·050%

The employment of molten pig-iron in the open-hearth furnace was not nearly so common as one had been led to expect, and, indeed, was far from being universal.

Of the open-hearth plants visited, those of the Pennsylvania Steel Co., at Steelton, Pa., the Cambria Steel Co., at Johnstown, and the Jones and Laughlin Co., at Pittsburg, were all employing cold pig for charging their open-hearth furnaces.

The use of hot metal for this purpose is in vogue at the Homestead works of the Carnegie Steel Co., and of course forms an essential part of the working of the Talbot continuous furnace at Jones and Laughlin's, Pittsburg.

With regard to one feature of construction of open-hearth furnaces, there would seem to be no consensus of opinion among American engineers. It is true that a very large number of rolling- or tilting-furnaces have been constructed in the United States, but it is not less true that in many of the plants recently erected the open-hearth furnaces have been of the fixed type.

Thus, the Homestead works of the Carnegie Steel Co., which is the last in the world which one could accuse of not being up to date, possesses three entirely distinct open-hearth plants, comprising respectively 12, 16 and 24 furnaces, in all 52 hearths, and not a single one of these is of the tilting or rolling type.

The point at issue between the supporters of the two types is chiefly in regard to the cost of repairs. True, the rolling furnace is a little cheaper in original cost, but this is a fixed sum and the interest on it small. It is the constant greater cost of repairs, due to greater tear and wear, particularly at the ports, which is the more serious item in the decision.

One or two open-hearth furnaces of special type should be described. The first of these was seen at the Steelton Works of the Pennsylvania Steel Co., and is known as the Campbell furnace. These furnaces are almost round in plan, but otherwise of the usual rolling type except that they are constructed with removable tops. The tops rest on the sides like a lid on a crucible, and when removed by means of an overhead crane, allow the furnace to be charged with material of any size which the furnace will hold. Whole ingots, long pieces of rail, and broken plates are charged in through the top on to a bed of lime, the lid replaced, and the melting down carried on in the usual manner.

This method of charging is said not to shorten appreciably the life of the furnace lining, but owing to the great loss of heat during charging, a 20-ton heat requires from 10 to 12 hours for completion.

The economies of such a furnace, of which two of 20-tons capacity are in use at Steelton, lie, not so much in the labour of charging, as in the negotiation of defective ingots and other large scrap which is so refractory to break.

In the No. 1 open-hearth department at Homestead steel works are three fixed circular furnaces with sliding tops into which "skulls," old rolls, and large pieces of scrap are charged bodily on to a bottom lined with lime and coke. No pig is charged, the furnace being simply a re-melting furnace for large scrap.

Practically every open-hearth plant in the United States

is now well equipped with overhead travelling cranes of large capacity.

No. 3 open-hearth department of the Homestead steel works is a model in regard to arrangement and equipment.

The twenty-four basic-lined open-hearth fixed furnaces are built on the ground level in two long lines back to back, with a wide space between the rows. This space contains a wide passage down the centre, and between this passage and the backs of the furnaces on each side, the ground is excavated to form alleys which hold the ladles into which the furnace-contents can be poured.

Over each set of twelve furnaces are three overhead travelling cranes of about 65—70 tons capacity. These span the entire space between the backs of the furnaces.

The space in front of the furnace is equipped with both Wellman charging-machines and overhead cranes. The former charge the scrap into the furnace and this is first heated up alone for two hours. The molten pig is then brought along from the metal-mixer to the top end of the furnace-shop by locomotive. At this point the cranes pick up the ladles from the cars, carry them to the furnace and pour the metal into the latter by means of a channel held in the charging-door by the Wellman machine.

A heat of 50—55 tons of metal requires about ten hours.

One great advantage the steel works in and round Pittsburg possess—the use of a cheap supply of natural gas of high thermal efficiency.

It is burnt at every available opportunity in an industrial establishment, for open-hearth furnaces, for reheating furnaces, for drying ladles, and many other purposes.

The one purpose to which it cannot be economically applied is in steam raising. Slack coal is cheaper.

Its employment for firing open-hearth furnaces does away with the necessity for half the regenerators usually

found in connection with such plant. So great is the efficiency of the gas that it is admitted to the side boxes up which the air travels, directly from the pipe which conveys it round the works. The hot spent-gases pass through a single regenerator which is used for pre-heating the air.

Perhaps the greatest difference between English and American conditions in steel-works practice is the very conspicuous absence of labourers in the American mills.

The large and growing employment of every kind of both propelling and directing machinery—electric-trolleys, rising and falling tables, live-rollers, side-racks, shears, machine-stamps, endless-chain tables for charging on to cars, overhead travelling cranes—is responsible for this state of things.

It is no exaggeration to say that in a mill rolling three thousand tons of rails a day, not a dozen men are to be seen on the mill floor.

To stand on the floor of such a mill and to witness the conversion, in the space of half an hour, of a red-hot steel ingot weighing several tons into finished stamped steel rails 90 ft. long, and all this practically by the agency of unseen hands, is to gain new ideas of the possibilities of mechanism—of the subservience of matter to mind.

This is the romance of steel evolved from the mind of the twentieth century American engineer.

In the system of rail rolling carried out at the Edgar-Thomson works, the ingots are removed from, as indeed they are charged into, the soaking pits by overhead travelling crane and placed one at a time in vertical positions upon a small electric car, whose front slopes at an angle of 50 degrees. This runs forward, and tilts over and deposits the ingot flat upon the live-rolls leading to the blooming-mill.

Ingot succeeds ingot regularly in this way at intervals of fifteen seconds.

The blooming-mill, which is three-high and continuous, is provided with horizontal rising and falling tables and side-racks, and blooms the ingots down to 9 in. by 7 in. without the intervention of hand-labour beyond that of the operator of the mill, who is placed on a platform elevated well above the rolls.

These blooms are now sheared to get rid of the piping, the waste ends falling into railroad cars. They are then cut into long and short lengths for rolling into rails of different sections. Both kinds go first, however, to re-heating furnaces, the smaller on electric trolley-cars, the larger on live-rolls. In connection with both re-heating furnaces there are excellent devices for handling the blooms. In the smaller, the blooms are pushed by a mechanical rammer from the trolley-cars mentioned into the furnace. They are drawn out by a machine resembling a charging-machine, with a long arm which can pick up blooms as by finger and thumb, then placed on a flat table, and the latter run to the rolls of the rail-mill. The arrangement in the larger furnace is similar, though not identical. The re-heating furnaces, like the soaking-pits, are heated by natural gas.

Following the course of the blooms destined for the larger type of rail, these first pass about four times through a preliminary mill which only puts on the flange of the rail. In the real rail-mill eight passes are necessary. The rail-mills are three-high and non-reversing, and take two rails at once, one through the larger roll and one through the smaller. Even so, no guide men at all are employed, this work being in the hands of the mill operator, through the agency of mechanical guides.

The Morrison-Kennedy process of rail rolling is in operation at this works in connection with the larger mill. It consists briefly in giving the rails the final roll at the lowest possible temperature above a certain limit.

Accordingly, on passing from the rail-mill, the rails run

on to a horizontal bed provided above with a reflector which forms a sort of air bath, and here they are cooled down for 45 seconds. They then receive a single final pass through a separate pair of rolls.

The rails then pass through a stamping-machine, are hot-sawn, cooled, straightened, cut and run down into cars. The output of the larger and smaller rail-mills, both working, as it were, on a single stream of ingots from the soaking pits, was at the time of the writer's visit, 3,000 tons in 24 hours.

Everything worked with perfect regularity, and, although there was a feeling of speed, there was an entire absence of that haste and rush which are rather the evidence of defective organisation than of rapid work.

The system of rolling billets and channels at Jones and Laughlin's works may now be described as illustrating the advances which have been made in the production of this type of rolled product at the best American works. The rolling of plates in three-high and universal mills of very large size—up to 152in. wide—at Coatesville and elsewhere has been fully described by Mr. Jeans.[1]

At Jones and Laughlin's works the ingots arrive on cars from the casting-house at one side of the billet-mill, and are there stripped by two pairs of electrically-worked ingot-strippers and placed by overhead crane in the soaking-pits which lie conveniently on the two sides of the stripping-house. They are removed therefrom by the same agency, and deposited on small cars such as the one already described in connection with the Edgar-Thomson steel works.

This carries them forward and deposits them on live rolls in front of a 40 in. three-high blooming-mill. In seven passes the ingot is bloomed down to 9 in. by 7 in., being controlled during the process by rising and falling tables on each side of the rolls; and this whole operation lasts two and a half minutes.

1 *American Industrial Conditions and Competition*, pp. 134-146.

A single operator, placed on a raised platform in front and a little to one side of the mill, controls the whole process.

A second operator, similarly placed, manipulates the live-rolls which bring the bloom to a three-high 28 in. billet-mill. Here the bloom is directed by a table of rolls, which, in addition to rising and falling, has also a lateral motion, so as to bring the bloom opposite the next pass, and which is provided with a mechanism to turn the bloom over through 90 degrees between each pass.

The products of the mill, now 4 in. by 4 in., are at this point divided into two streams, alternate billets being taken to a Morgan continuous-mill, the remainder carried by live-rolls a considerable distance underground to another mill to be rolled into channels.

The Morgan mill consists of a series of eight rolls in one straight line, each succeeding one being smaller in the pass, and further removed from its predecessor than the last. Needless to say, the blooms pass through this mill quite automatically. They emerge therefrom as 1 in. by $\frac{3}{4}$ in. billets, and are slowly passed, cooling meanwhile, down the successive steps of an inclined table, into a railway car standing below.

CHAPTER VI.

American Labour and Education.

The greater part of what has been said as to the American iron and steel industry and its organisation would be meaningless apart from a consideration of the personnel of American industrial life. The human element is the most important, indeed the only essentially important, consideration, from this or any point of view; it is at the same time the most difficult to speak of in this connection. Not only to observe him in his work and play, in his home life and in his public life, but also to see things from his standpoint, to enter into his view of life—this would be necessary thoroughly to appreciate the American workman in his relation to industry; and it will be admited that this is impossible in a seven months' visit.

It is with no little diffidence then that the writer offers the following remarks on this important subject. In the first place, it is impossible to attempt to sketch in general terms the characteristics of the American workman. Made up of such diverse elements as the native white American, the Negro, the German, the Irishman, the Pole, the Italian, the Hungarian, the Finn, the Scandinavian, the Dutch, the Scot, the Englishman and Slavs of various kinds, to name only the more prominent nationalities, the American industrial community is the most cosmopolitan in the world. It is not surprising that the American working man conforms to no fixed type.

It has been the practice in the past, and is still the case to a considerable extent, for each of these different

nationalities to be engaged in a particular class of work for which they were thought to be most suited. Thus, the Scandinavians are largely engaged in farming in the north-west; numberless Lancashire cotton operatives have helped to build up the New England cotton industry; digging and navvying work is done almost exclusively by Italians; and the mines of Pennsylvania and Illinois are very largely worked by shifting populations from Southern and Eastern Europe. It was at one time thought that none but Welshmen could roll steel, none but Irishmen manipulate blast-furnace fronts, and none but Germans work in the machine shops. But this feeling is almost dead, and every man has now an equal chance to show his ability. In the South black labour is almost universal, but the negroes have made little headway among the manufacturing industries in the Northern States. This is to be attributed partly to social reasons—the refusal of the whites to associate with negroes in their work, and partly to economic reasons—the inefficiency of black labour, due largely to lack of capacity for regular steady work.

Black labour is met with in a few of the steel works in the North, in some cases on open-hearth furnaces, but for the most part doing the heavier work of cutting and shearing plates. Its presence is to be attributed to scarcity of other labour, and not to its cheapness, negroes receiving on open-hearth furnaces the same remuneration as the whites for the same work.

Needless to say, the efficiency of labour of different kinds varies considerably, another reason which makes it impossible to speak of American labour as a single quantity. Two views of black labour were put before the present writer. One was that of a black waiter in an hotel in Cleveland, Ohio. This man had been educated for the ministry at the Tuskegee Institute, the college for negroes in the South, which is directed by Mr. Booker T. Washington.

He was unable to complete his course owing to lack of funds, and had undertaken his present work in order to save sufficient to be able to graduate in divinity. He stated that the work of the Tuskegee Institute fully proved the capacity of the negro to learn and engage in the skilled trades, and that black labour was rapidly making its way in the industrial world of the Southern States. In the North, class prejudice still denied the ability of the negro for anything higher than the roughest and heaviest of manual labour and for menial service in hotels and the home. It was practically impossible for a black man, be he never so able, to obtain skilled work in the Northern States.

As exhibiting the other point of view, the Northern employer points to the inefficiency of black labour, arising largely from its inability or lack of desire to do steady routine work. The negro has no instinct beyond the satisfaction of the merest bodily wants; he is quite lacking in the power to save, and in that desire to get on and improve himself which characteristises nearly every kind of white labour in the United States. A negro will work three days and spend the next three lying in the sun, smoking and drinking.

Probably both these views are correct in the main. There is little doubt about the laziness and shiftiness of the average negro; there is less as to the cruelty of the hatred which is constantly being aroused in the white American against the "nigger." English people have little conception of that terrible race feeling which finds its worst expression in the frequent lynchings which take place in every part of the country.

The Germans are claimed to form some of the most promising raw material for the building up of steady, industrious, law-abiding American citizens. They are to be found in large numbers in Eastern Pennsylvania, in the Lehigh Valley and surrounding districts, where they

have preserved their own language, though in a corrupted form, in a most remarkable way. Many of the older generation have never learned to speak English, and the language known as Pennsylvania Dutch is the rule rather than the exception among the group of ironworks which centres round Allentown and Bethlehem. Speaking of the different kinds of labour employed in the blast-furnaces of America, Mr. Axel Sahlin [1] says:—"The cheapest and best blast-furnace labour is found in Eastern Pennsylvania, where the crews are recruited from the native Pennsylvania Dutch. These men are regular and saving in their habits, and though their pay is not high, many of them own their own houses, and feel more or less identified with their towns and the business interest for which they are working. Without being particularly bright or of superior intelligence, these men are, therefore, very valuable as blast-furnace workers."

This cheap and regular supply of efficient labour is the one clear advantage which this group of somewhat out-of-date furnaces possesses.

It was surprising to learn, in view of the high value generally attached to hereditary skill,[1] that the American Sheet Steel Co. on opening up works at Vandergift, Pa., some forty miles from Pittsburg, about six years ago, had been almost entirely dependent upon "green" labour, that is, unskilled farm-hands from the country districts round about. Instead of this being looked upon as a misfortune, it was regarded as a distinct advantage to have a labouring element of fine physique upon which to draw. Four years' experience had proved that strong muscles and healthy frames were an asset at least equal to "hereditary skill." This well illustrates the adaptibility of the native white American.

But greater than its cosmopolitanism, though no doubt

1. *American Industrial Conditions and Competition*, p. 504.

1. Marshall, Economics of Industry, p. 152.

partly arising from it, the most characteristic feature of American industrial life and the most far-reaching in its effects is what may be shortly termed mobility of labour, or what an eminent English economist has described as economic freedom.

What first strikes a foreigner on landing in America is the democratic spirit which is abroad, and what impresses itself upon him more and more as he stays there is the genuineness of this spirit.

Now, whatever may have been its results in the political world, and this is not the place to discuss them, the application of the democratic idea to industrial affairs has been productive of nothing but good.

This feature of American life has not, we think, been sufficiently realised, or at any rate emphasised, by writers on industrial conditions in that country.

It exhibits itself in a multitude of directions. Under a competitive system, a large degree of mobility, not only in the various grades of labour themselves, but also between the different grades, allows the best man to come rapidly to the top, and promotion is very much quicker in America than here. The knowledge that every man, by a combination of capacity and industry may in a very real sense rise to the highest positions in the industrial world is an incentive to effort only equalled, perhaps, by the realisation that lack of these qualities will as surely lead to the wall.

This does not mean to say that every day-labourer rises to the managership of the works in which he is employed. Every man has his limit, but not every system allows or induces a man to work up to and remain at his limit, as does that of America. Moreover, every man is encouraged to develop himself to the fullest extent, by the educational facilities which the State not only provides, but, up to a certain point, insists on.

A successful educational system must be the result of joint action between the parents and the State. Its effect

upon the industrial system is determined in a minor degree by the attitude of the employer of labour towards the trained man. The American public thoroughly believes in technical and commercial education because it knows that such a training has a high market value.

On its part, the Government has pursued an enlightened and progressive policy in the belief that an educated proletariat is not only a high commercial asset, but a guarantee of order and good government.

In the first place, there is a continuity—hitherto wanting in this country—extending through all branches of public education, elementary, secondary, technical and university.

Education in the public schools is free, compulsory and non-sectarian. It is perfectly continuous through the elementary and secondary (or high) schools, both branches being under a single authority. Moreover, by the system of "accredited" schools, that is, high schools which have been examined and declared efficient by the university to which they are accredited, students pass quite automatically without entrance or matriculation examination from these schools into the university.

Each State makes its own school laws and decisions. The State of Pennsylvania, the most important industrial Commonwealth in the Union, makes provision for a free education from the age of six to that of twenty-two.

It compels attendance between the ages of eight and sixteen, with the proviso that children who are in regular employment, and whose assistance the parents require, are granted permission to leave school at the age of thirteen.

Most of the children enter school at the age of six, and spend four years in the primary grades and four years in the grammar grades, the last year being a special preparation for the work of the high school. They pass into the high school at fourteen and remain there two, three or four years, according to their own and their parents' wishes.

Some of the pupils matriculating from the high schools enter the State College, where tuition is free, but books and board have to be paid for. Others go on to the larger universities or smaller colleges where the fees average £30 a year during a four years' course.

In the middle West and West, however, the State universities, which take an almost equal standing with the older private foundations of the East—Harvard, Yale, Cornell, Princeton and Columbia,—grant a free education to students from their own States.

Students are continually passing from school into the industries from the age of thirteen upwards, but the percentage which obtain a college or university training is very high.

In a small industrial town of about eight thousand inhabitants, the number of pupils in the four high school classes (ages 14—18) was 100, about 18 graduating from the highest class, as against 60 that entered the lowest.

In Allegheny, a large manufacturing town which stands to Pittsburg as does Salford to Manchester, the total school attendance out of a population of 130,000 was 20,000. Of this number 600 were in the high school. The proportion of the school population which remains at school after the age of thirteen, is from 20—25 per cent. This small number was accounted for by the presence in Allegheny City of a large number of poor foreigners, who require their children's assistance at the earliest available moment.

The great difference between elementary education in this country and America lies in the personnel of the teacher, and this not so much in regard to his academic attainments as in the general culture and the broader outlook on life which the American possesses. This arises partly no doubt from the absence of distinction between elementary and secondary teachers which the closer relationship between the two branches of education has brought about.

In the organisation of elementary education, manual training work for boys and domestic science for girls play an increasingly important part.

The object of the manual training is not to teach the boys the elements of mechanical trades, but simply to train hand and eye. The code in American education is no longer the three R's, but the three H's: heart, head, and hand,—the development of power from the hand, direction from the head, inspiration from the heart.

The position which the high school fills in the scheme of public education is well typified by the work of a school of this type in the small industrial town in Pennsylvania already referred to.

The curriculum is divided into four branches in each year—Latin (for which German may be substituted), mathematics, natural science, and history and literature. The spirit of the teaching was well expressed in some remarks made to the author by the headmaster of the school. The aim of the high school training, he said, was to fit the pupil, not so much to earn his living (that would take care of itself) as to live his life fully, to develop all the faculties with which he had been endowed, so as to appreciate the best and highest things in life—in short, to produce a cultured man or woman. This was a high ideal, and gave a splendid basis on which to erect a scheme of sound higher education, whether technical or academic.

The system of technical education has been well analysed by Mr. R. Blair, one of the members of the Mosely Education Commission sent out to America to investigate the influence of education on industry; and his report to the Commission has been largely drawn upon in what follows.

Technical instruction, which, in the main, this country provides for in evening schools, is carried out in America, as in Germany, for the most part in day schools. Institutions providing technical instruction in America may be roughly

divided into three classes, according to the rank in the industrial world which its pupils afterwards assume. First come the Scientific and Professional Schools of the large Universities, and the best Technological Institutes of the type of the Stevens Institute at Hoboken, N.J., the Massachusetts Institute of Technology in Boston and the Case School of Applied Science, Cleveland, Ohio. These are engaged in the preparation of the "leading officers" of the industrial world, the "captains of industry." The science schools of the universities do much the same work as our own colleges, except that the instruction is perhaps a little more practical in its character and less attention is devoted to pure research. The best technological institutes have no prototype in this country. They provide a technical training as high in standard as the more academic courses of the universities, and based on a sound foundation of theoretical science. The requirements for entrance are very high, and the average age of students entering will be about 18.

In the scientific colleges and schools of technology (day institutions) of the United States in 1900 there were:—

Students of	Agriculture	2,852
"	Mechanical Engineering	4,459
"	Civil Engineering	3,140
"	Electrical Engineering	4,459
"	Mining Engineering	1,261
	Total	14,267

In addition there were 10,925 students of general science courses (University and Technological), including Applied Chemistry.

Of the 1,608 day students of the Massachusetts Institute of Technology in 1902–03, 22·5 per cent. were between the ages of 16½ and 18, and 77·5 per cent. were over 18. None were below 16½, and almost 15 per cent. were over 20.

While 408 students were admitted in 1902, 104 were rejected as unfit.

The advantage which this Institute derives from the imposition of a severe entrance examination has been constantly insisted on by educational experts

The fees at these higher institutions are, in the East, high, ranging from £30 to £50 a year. But no bright and deserving student need be debarred from their privileges on this account. In addition to free scholarships granted in some cases by the State, in others by the institute itself, there are private funds providing for needy students which are administered with due secrecy by the authorities. Moreover, in nearly every such institution there exists some form of self-help bureau, an agency for securing all kinds of work for students, such as waiting at table, collecting accounts, typewriting, and trouser pressing, whereby they are enabled to earn their board and work their way through college.

The American students are extremely independent, and prefer to undertake even the most menial of work rather than accept charity, as a means of getting an education. So much is this the case that instead of a scholarship being regarded by the holder as a mark of honour, as little is said of these financial aids as possible. Another reason for this is that these emoluments are never awarded as the result of a competitive examination, but always after strict private inquiry into the financial position of the applicants.

One of the main causes which conduces to the success of higher technical education in respect of the members which take advantage of it, is the promptness with which the students are snapped up by industrial firms immediately their courses have been completed. Indeed, many of the men are engaged long before the end of their last college session.

Now this is not to be attributed to any sentimental

attitude on the part of the employers; the American is the last person to introduce sentiment into business. On the contrary, the success which increasingly attends the development of higher technical education in the United States is due to the liberal attitude of mind which the entrepreneur maintains towards new ideas, and the practical and utilitarian character of the students' training; and both these are traceable to the intimate connection which exists between the "schools" and the industries.

Many of the employers are college men themselves, and are in thorough sympathy with the educational work. They afford the students every opportunity of keeping in touch with industrial conditions, and they have no prejudice against an educated man as such. Again, the majority of the professors and teachers are engaged in industrial work in addition to their teaching duties, and there is a continual flow of men from the teaching profession into the industries and from the industries back to the teaching profession. All this reacts upon the success of the teaching, giving it that practical bent which prevents the college man from feeling at sea when he gets inside a works. The engaging by professors in consulting work of a private character is defensible on many grounds, but perhaps most on this, that it secures for education the services of the best men, who but for this (not inconsiderable) extra source of income would be driven altogether into industrial pursuits. And it cannot be said that the students suffer from lack of attention.

The greater popularity of higher education in America than here is but another expression of that mobility and state of flux which characterises the human element of the industrial world of the United States. The ease with which men move from one industry to another is hardly greater than that with which they move from one grade of labour to a higher, often by the assistance of educational

attainments. And the inducements to the worker to sacrifice in order to improve himself are to be found in the attitude of the employer and the kindly sympathy extended by public opinion to those working their way through college.

The second grade of technical institutions comprises those which provide the petty officers, men to hold the intermediate positions below the chief engineer and general manager on the one hand, but above the skilled mechanic on the other. These institutions attempt to graft some technical instruction on to a general education which is equivalent to the first two years in the high schools. Consequently the age of entry of the students is 16 or 17. The courses are shorter and less advanced than those of the higher institutions, lasting two years in the day school, and four or five years in the night school, and covering somewhat more than would be taken in a regular four years' course in one of our own evening technical schools. A characteristic feature of every educational institution in America, even of such a one as the Stevens Institute, which is purely a school of mechanical engineering, is the time spent on English, and often also on some modern language.

The third class of institution providing technical instruction is to be found in the trade schools which train the "hands." These are typified by the Fulton-Cutting Trade School in New York City. Here for a nominal fee youths and men can obtain, in either day or evening courses, instruction in the various trades: brick-laying, plastering, plumbing, painting and decorating, carpentering, smith's work and so on.

The students are either those already engaged in the trade they are learning, or else those employed in some occupation which gives them no scope for advancement. Since the apprenticeship system has fallen into decay, instruction at a trade-school is practically the only means

of entrance to some of the trades, and while the school does not pretend to turn out skilled workers, it does convert unskilled into partly-skilled labour, and give the former a lift upwards in its attempts to rise.

The general absence of evening schools in the United States, except in a few of the large cities is partly, though very inadequately, made up by the numerous correspondence schools, of which the first and largest is that at Scranton, Pa., which, during the last ten years, has enrolled 600,000 students for study by correspondence.

This institution aims to help the artisan class by instruction of much the same standard as that laid down by our own Education Department. With all the defects inherent in any system of tuition by correspondence, this school has been a means of rising in the ranks of industry and commerce to hundreds for whom it was the only means of continued education.

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